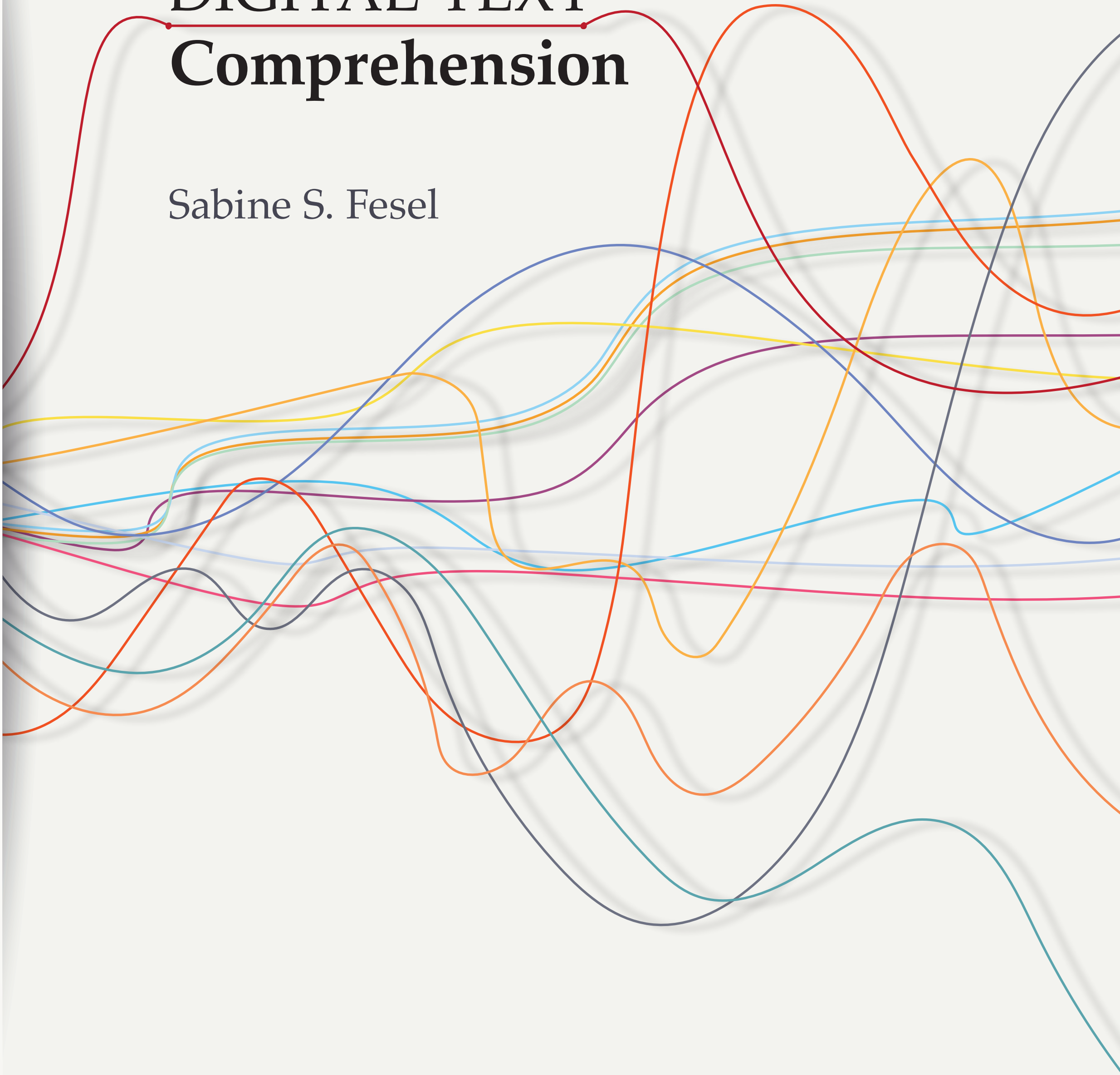
Children's DIGITAL TEXT Comprehension

Sabine S. Fesel



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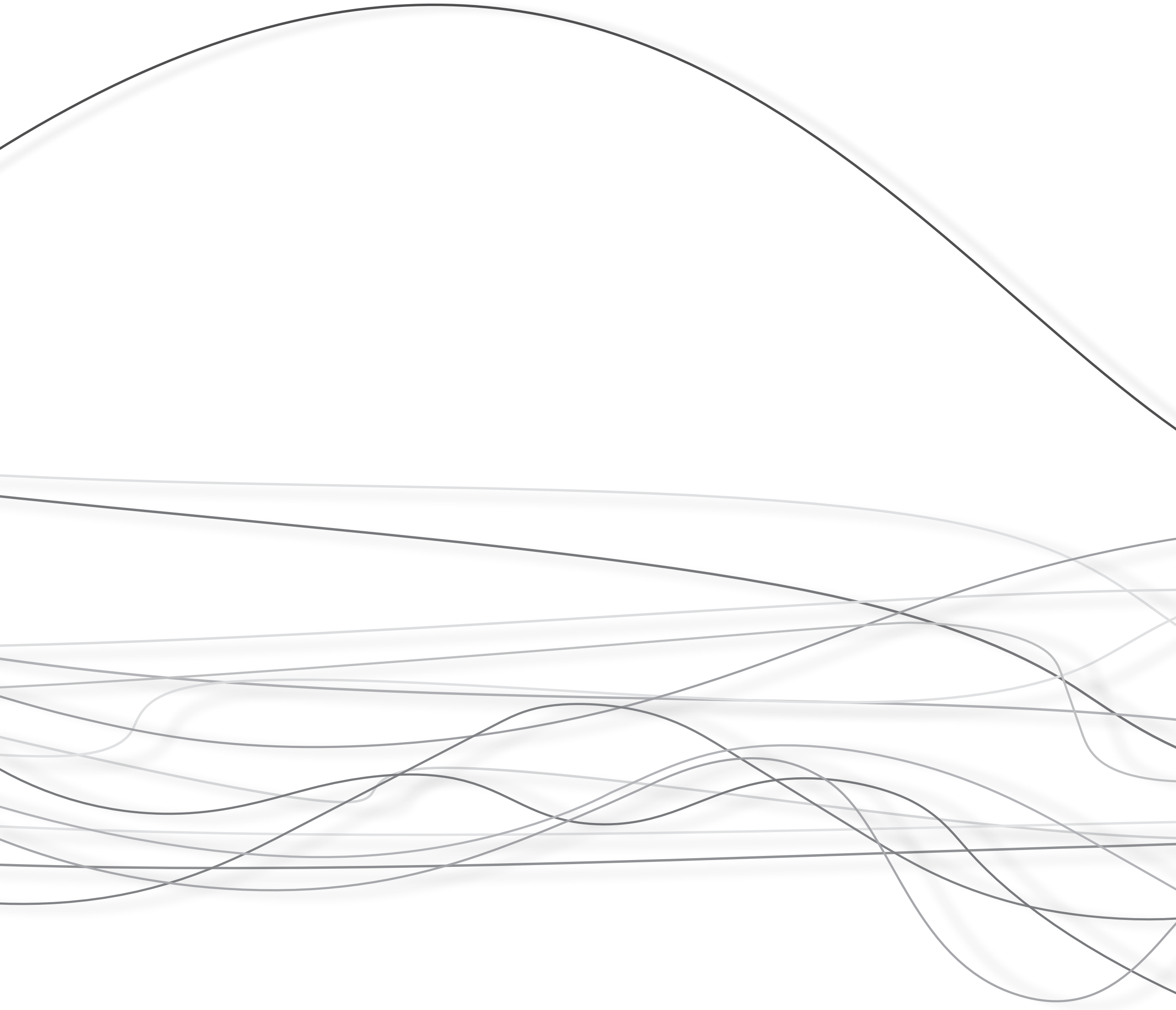
Contents



Chapter 1

General INTRODUCTION

The widespread development of the Internet has put forth a different text genre, known as digital text. Most often, digital text takes the form of nonlinear hypertext with embedded hyperlinks. The ubiquity of digital text as a practical alternative to printed text at primary schools as well as secondary schools reveals its important role as an information source in children's acquisition of knowledge (Burnett, 2009; Moos & Marroquin, 2010; Salmerón, Cañas, Kintsch, & Fajardo, 2005).

Research has shown inconsistent results about the relative effectiveness of comprehending and learning from digital text versus traditional printed text in adults. This can partly be explained by individual differences in prior knowledge. Prior knowledge helps the reader to find a coherent navigational path, and is a main determinant of successful hypertext reading (Amadieu, Tricot, & Mariné, 2010; Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009). On the one hand, researchers showed that specific hypertext features, such as hyperlinks and graphical overviews may help the reader to compensate for shortages in prior knowledge or reading skills (Amadieu et al., 2010; McEneaney, 2003; Naumann, Richter, Flender, Christmann, & Groeben, 2007; Puntambekar & Goldstein, 2007). On the other hand, it was shown that low-prior knowledge and low reading skill can be easily overstrained by such hypertext features (Bezdan, Kester, & Kirschner, 2013; DeStefano & LeFevre, 2007). Indeed, researchers have evidenced that the risk of disorientation, cognitive overload, and getting "lost in hyperspace" are high for low-prior knowledge readers who show incoherent navigational patterns (DeStefano & LeFevre, 2007).

Children as participants in digital text comprehension research are under-represented. They can often be considered low-prior knowledge readers, but may face problems that cannot directly be compared to those of adults with low-prior knowledge. In order to arrive at a better understanding of the processes of beginning digital text reading, in the present thesis children's comprehension and learning of various digital text types was examined.

Digital Text Features

Digital text is linear text displayed on a computer screen. Hypertext is a special form of digital text built up of unique text features as embedded hyperlinks and navigable overviews with a nonlinear text structure. In contrast to an overall linear or sequential reading behavior in traditional linear text, in hypertext the reader can navigate in a nonlinear format, due to the specific text features (Kang, 2014). This navigational path is guided by the reader's skills and amount of prior knowledge of the topic.

According to the Cognitive Theory of Multimedia Learning (Mayer, 2005), linguistic markers that show semantic relations may help the reader to select, organize, and integrate information during the reading process and give navigational guidance in digital text (Amadieu & Salmerón, 2014). Hyperlinks and navigable and graphical overviews are two of these markers. *Hyperlinks* may function as cross-references. They can be embedded on different pages of one hypertext environment and linked in hierarchical or networked structures in the space of the same hypertext environment. They can also externally link to another hypertext environment (DeStefano & LeFevre, 2007). Hyperlinks may facilitate text structure understanding on a microlevel (Gall & Hannafin, 1994; Shapiro & Niederhauser, 2004). *Navigable and graphical overviews* may help to identify the macrostructure of a digital text and foster coherent navigation in difficult hypertexts (Amadieu & Salmerón, 2014; Salmerón et al., 2009; Vörös, Rouet, & Pléh, 2011). They can support deeper learning in low-prior knowledge (adult) readers because they are external representations of the semantic structure of a hypertext. This type of overview may facilitate the understanding of conceptual relationships between different hypertexts and help the reader to find a coherent reading path (Amadieu & Salmerón, 2014; McNamara & Shapiro, 2005).

Because of the specific text features that permit unique navigational flexibility in information retrieval in hypertext, there is a different reader-text interaction compared to reading linear text. The reader of hypertext has to determine coherence during reading instead of the author. And in hypertext reading, there is a clear shift from the author to the reader in the control of information access. The non-linear design of hypertext allows the reader to acquire comprehension in a highly flexible and self-guided reading process in which the reader determines the navigation pattern. Of course, there is some flexibility in reading books or traditional linear texts (e.g., induced by the table of content), but this is quite different from the non-linear reading behavior in hypertext where the reader determines text coherence during the reading process and not the author (Foltz, 1996).

Digital text may be problematic for low-prior knowledge readers or less skilled readers. Readers who do not accomplish coherence in hypertext reading can easily become disoriented due to a high cognitive load (Kumbruck, 1998; Mangen, 2008; Mangen, Walgermo, & Brønnick, 2013; Waniek & Ewald, 2008). Maintaining coherence during the reading process and making appropriate navigational decisions may be the main challenges for readers of digital text and especially hypertext (Bezdan et al., 2013).

Previous research showed that more 'hand holding', in terms of a hierarchical structure or well-defined overviews may be advantageous, in particular for low-prior knowledge adults (Amadieu & Salmerón, 2014; Amadieu et al., 2010; Foltz, 1996; Jin, 2013; McNamara & Shapiro, 2005; Potelle & Rouet, 2003; Shapiro

& Niederhauser, 2004). A hierarchical structure supported the reader to follow a coherent navigation path, reduced disorientation, and improved comprehension (Amadieu et al., 2010). Hierarchical text and especially hierarchical hypertext already gives an implicit structural support, because the texts are linked to each other to some extent. A closed hypertext contains inter-textual hyperlinks that link text nodes within one hypertext system. Therefore, a closed hierarchical text is already by definition more coherent compared to networked-linked text. Research revealed that children around the age of 11 years are able to follow a coherent navigational path (Salmerón & García, 2012). Children read coherent links and related the underlying propositions while at the same time pausing the reading process to focus on the overview (Salmerón & García, 2012).

In sum, hyperlinks and graphical overviews in digital text can be considered linguistic markers which give the reader flexibility in determining a coherent reading order. However, at the same time these digital text characteristics may produce added complexity regarding the reading process and outcomes in low-prior knowledge adults (Shapiro & Niederhauser, 2004). The effect of digital text features on reading comprehension has not yet been examined in children.

Digital Text Comprehension

In line with the lexical quality hypothesis, word decoding and vocabulary are basic reading skills that would also apply to digital text comprehension (Perfetti, 2007). But, next to lexical processes and sentence comprehension (Shapiro & Niederhauser, 2004), reading digital text for comprehension demands additional cognitive processes. The digital text features that cause the reader to select a coherent reading order during reading may impair their comprehension process (e.g., Amadieu, Tricot, & Mariné, 2009; Otter & Johnson, 2000; Salmerón, Kintsch, & Cañas, 2006; Zumbach & Mohraz, 2008). Like it is the case in linear text, this comprehension process combines conceptually driven processes (top-down) and data-driven processes (bottom-up) that contribute to the construction of a mental situation model according to the Construction-Integration model (C-I model; Kintsch, 1998; Kintsch, 2005; Woolley, 2011). During the comprehension process, readers start with the construction of a text-base understanding. Deeper comprehension takes place when they integrate information from the documents into a situation model. Learning from a text is regarded as the retrieval or recall of the appropriate situation model from memory. Therefore, a coherent mental model can be seen as the goal of both comprehension and learning (Kintsch, 2005; Woolley, 2011).

Adult reading comprehension depends on prior knowledge and reading skills, on the one hand, and on text characteristics, on the other hand (Amadieu et al., 2009; Foltz, 1996; Madrid, Van Oostendorp, & Melguizo, 2009). The increased learner-control in hypertext reading is assumed to support comprehension and learning from hypertext, as the reader is engaged in active reading (Möller & Müller-Kalthoff, 2000). This would lead to a coherent navigation pattern, which is important for successful comprehension and learning (Foltz, 1996; Salmerón et al., 2006; McNamara & Kintsch, 1996). However, a review on adult hypertext reading showed that reading hypertext often causes an increase in cognitive demands, resulting in additional cognitive load, which may impair reading comprehension (DeStefano & LeFevre, 2007).

Children read with less automatized reading skills and may find it hard to compensate the additional cognitive demands of hypertext reading, resulting in difficulties to navigate in a coherent manner (Lawless, Mills, & Brown, 2003; Salmerón & García, 2011, 2012). A meta-analysis on the effect of technology environments showed an overall positive impact on middle-school students' comprehension outcomes (Moran, Ferdig, Pearson, Wardrop, & Blomeyer, 2008). So far, however, only one study compared children's reading comprehension in printed versus hypertext (Salmerón & García, 2012). In this study, it was hypothesized that structural features in hypertext might facilitate children's comprehension. The results were in line with previous research with adults, showing that hypertext with navigational overview facilitated comprehension at the situation model level compared to printed text. Furthermore, the results showed that hypertext did not negatively affect children's comprehension on the text-base level. A cohesive selection of links as well as an initial processing of the overview was positively related to comprehension in sixth-graders (Salmerón & García, 2012).

Next to the above mentioned studies, research on digital text comprehension also used comprehension tests in hypertext in which participants do not have the opportunity of looking back in the digital text (see Salmerón et al., 2005; Amadieu et al., 2009). Next to comprehension, these tests also tap how much the reader recalled. The comprehension tests measured *after* reading evidenced an influence of the memory capacity of the reader. Of course, the ability to memorize, recall, and learn depends on successful comprehension on different levels. However, the effort to memorize can interfere with comprehension. In hypertext, the changed reader-text interaction and the coherent navigational demands may affect comprehension and learning, because the reader has to remember the reading order, the reading goal and focus on the navigational process during reading (DeStefano & LeFevre, 2007). The learning process which is the elaboration or modification of cognitive structure tested after reading should be distinguished from comprehension tests during reading even though the fact that learning and comprehension are theoretically inseparable (Smith, 1975).

Learning from Digital Text

Learning from digital text involves the reorganization of its underlying cognitive structure (Shapiro & Niederhauser, 2004). A well-defined and clear structure of digital text and the presence of a graphical overview may therefore be important for the reader (Amadieu & Salmerón, 2014). A well-designed hierarchical hypertext may particularly support learning in low-prior knowledge readers if it explicitly points out the relationship between ideas and aiding meaningful understanding (McNamara & Shapiro, 2005; Shapiro & Niederhauser, 2004). Some previous hypertext studies in low-prior knowledge adults showed that the number of nodes read affected the text-base level, while the reading order affected the situation model of the reader (Madrid & Cañas, 2009; Salmerón et al., 2006). Salmerón et al. (2005) also showed that low-prior knowledge readers tend to apply a coherence strategy to reduce cognitive load and to enhance learning. This strategy aids to accomplish a coherent reading order by focusing on the relationship between ideas. Amadieu et al. (2010) examined the influence of text structure in high and low-prior knowledge skilled readers. Their results indicated that a hierarchically structured hypertext is most appropriate for the knowledge acquisition process of low-prior knowledge readers (Calisir & Gurel, 2003; Calisir, Eryazici, & Lehto, 2008). Furthermore, research revealed a direct effect between an overview processing strategy and learning from text (Salmerón et al., 2009). In particular, reading a graphical overview at an early stage of the reading process of a difficult hypertext enhanced learning in adults (Salmerón et al., 2009). In only one study, the learning from hypertext in children was examined (Sahin & Alsancak, 2011). One group of children had to scroll down to read the entire text, the other group had to read shorter pages, but had to click to read the next page and to progress in reading. It was found that children in the scrolling group outperformed children in the shorter pages group.

In order to foster the learning process and learning outcomes of reading hypertext, the teaching of learning strategies that are specifically tailored to digital text may be helpful. Successful strategies have been observed in adult, skilled readers of hypertext, who use adjusted metacognitive learning strategies when reading hypertext (Azevedo & Cromley, 2004). It is suggested that learners should be encouraged to think about their navigational path, the reading order and the relationships between nodes to take advantage of the digital text features (Azevedo & Cromley, 2004; McNamara & Shapiro, 2005; Shapiro, 2008). However, from an aptitude-treatment interaction perspective, less skilled readers may be overtaxed by the cognitive demands of a training and the digital text features (Naumann, Richter, Christmann, & Groeben, 2008). Naumann et al. (2008) showed that learners with low working memory capacity or low reading skills performed worse in both a cognitive and a metacognitive hypertext training condition. To overcome these additional cognitive demands of a strategy training, an external control may be supportive. Indeed, during a metacognitive hypertext training, a paper prompting card of the strategies supported learning related to transfer of knowledge (Bannert, Hildebrand, & Mengelkamp, 2009).

The Present Thesis

In the research conducted so far, the relative importance of digital text features for comprehension and learning in low-prior knowledge adult readers has been highlighted. It is assumed that a hierarchical text structure as well as graphical overviews may support reading digital text. However, the influence of different digital text types on children's building of a situation model and comprehension as well as their knowledge acquisition remains unclear. Previous research also revealed that cognitive and metacognitive strategies are of special importance in learning from digital text because these strategies help the reader to find coherence and thus support comprehension. So far, however, no study examined the effect of hypertext strategy training on learning in children. In order to make strong claims about the efficacy of digital text comprehension in children, there is an urgent need for a new line of developmental studies (Moran et al., 2008).

The present dissertation examined how children in the upper primary grades and early secondary grades comprehend and learn from different digital text types. A distinction was be made between (linear) digital text and hypertext with hyperlinks, respectively with and without graphical overview. In each of these text forms, an attempt was made to uncover individual reading comprehension processes and the quality of children's knowledge structures related to comprehension. Next, the effect of various digital text types on children's navigation and learning was examined. In addition, the effect of a hypertext reading strategy training on children's learning from digital text was examined.

The following research questions were addressed in the present thesis:

1. How do children comprehend different digital text types with specific hypertext features?
2. How do children learn from different digital text types with specific hypertext features?
3. How can children's learning from hypertext be fostered?

To answer the research questions, four studies were conducted. Two studies focused on digital text comprehension in children in the upper grade of primary school, one study on the navigation and learning from hypertext in early secondary school children, and one study examined the effect of a strategy training on primary school children's learning from hypertext. Accordingly, the present dissertation includes a collection of four scientific articles that have either been accepted for publication or (re-)submitted for publication in international journals.

Methodological Issues

To examine children's hypertext comprehension in an educational setting, the choice of assessment is important to grasp children's situation models. Accordingly, an important point to consider when investigating the effect of hypertext is the type of comprehension and learning processes or outcomes being assessed (Shapiro & Niederhauser, 2004). To understand children's digital text comprehension, it can be recommended to examine how readers construct situation models and how these mental models differ across different text types. To examine reading comprehension and learning from text, the conceptualization of mental models in reading comprehension is challenging for educational researchers, because a variety of measures exists.

Three main assessments, suitable for children, have been used in the current thesis. The first assessment concerns reading comprehension questions to give insight into the reader's current mental models while focusing on aspects of the mental model specified by the questions. The questions can be explicit (literal) or implicit (transfer) questions. To answer explicit comprehension questions, the reader primarily focuses on the text-base level in search of literal information in the text. To answer implicit questions, a reader has to integrate his prior knowledge and make inferences about the whole text to show deeper comprehension (Kintsch, 2005). A second assessment suited for extracting children's mental models is the mind mapping method. In comparison to comprehension questions, the reader's mental model is not guided by the question type. A reader can mind-map his/her comprehension process during reading or after reading, giving a visualization of the mental model that is stored in memory. As a third assessment, the pathfinder approach can be seen as a technique to examine reader's structural networks of comprehension, which was already applied to hypertext in previous research (Madrid et al., 2009). This approach is simply a subject's estimate of relatedness of pairs of main concepts extracted from a text (Schvaneveldt, 1990). The approach measures the mental model of a reader indirectly via judgments of relatedness (Madrid et al., 2009; Ifenthaler & Pirnay-Dummer, 2014). Via a computer based relatedness-judgment task and a pathfinder scaling algorithm reader's knowledge representations can be measured and the similarity to, for example, expert knowledge representations can be calculated (McDonald, Paap, & McDonald, 1990). To measure the knowledge structures, a three step approach is necessary: (i) Proximity data are collected using a relatedness-judgment task in which subjects rate the relatedness of pairs of main concepts of a text, (ii) A Knowledge Network and Orientation Tool (KNOT software, Interlink, Inc., 1998) calculates with a pathfinder approach the most salient relationships in network structures resulting in pathfinder networks (Pfnets), and (iii) A subjects' Pfnets similarity (intersection divided by the union to two Pfnets) with a referent, for example an expert, can be calculated (Clariana & Wallace, 2009; Ifenthaler, Pirnay-Dummer, & Seel, 2010; Madrid et al., 2009).

One advantage of using reading comprehension questions is their educational implementation, because in educational settings it is very common that children have to answer comprehension questions to estimate their comprehension. However, there is no visualization of the situation model and the retrieval is based on the type of questions. An important advantage of the mind mapping task is its visualization of the comprehension outcome. Via simple one-word concepts and links, a child can easily reproduce his or her understanding of the topic. The number of concepts is open and the allotted time influences the number of concepts included in the mind map, as well as its complexity. Furthermore, in contrast to mind mapping, experience with the task does not influence the results. The number of concepts is determined beforehand; therefore the complexity does not vary, making it possible to compare the knowledge structures to a referent. All three approaches are appropriate for children and can be implemented in an educational setting.

Outline of The Dissertation

In order to answer the first research question related to children's digital text comprehension, two studies were conducted. In Chapter 2 ("Individual variation in children's reading comprehension across digital text types") the predictive value of lexical quality measurements, prior knowledge, working memory, hyperlinks as well as overviews of primary school children's reading comprehension was examined. Chapter 3 ("Quality of children's knowledge representations in digital text comprehension: Evidence from pathfinder networks") extends the results of Chapter 2. The quality of children's structural knowledge representations was examined across four digital text types.

To answer the second research question, related to children's learning, in Chapter 4 ("How hypertext fosters children's knowledge acquisition: The roles of text structure and graphical overview"), the influence of different digital text types on children's navigation and learning was addressed. It was investigated how secondary school children navigate across four digital text types: linear digital text (LDT), digital text with overview (DTO), hypertext (HT) and hypertext with overview (HTO). Furthermore, the difference in learning from those text types was examined.

To answer the third research question, related to the effect of a hypertext training, in Chapter 5 ("How strategy training and mind mapping facilitates children's learning from digital text") the effect of a hypertext reading strategy training on primary school children's learning was examined. In a pretest-posttest design a training group and a control group were tested.

Finally, in Chapter 6, general conclusions of the present thesis are presented and a discussion of the results, based on a summary of the main results of the present thesis. The final chapter discusses also some limitations of the present thesis as well as implications for future research.

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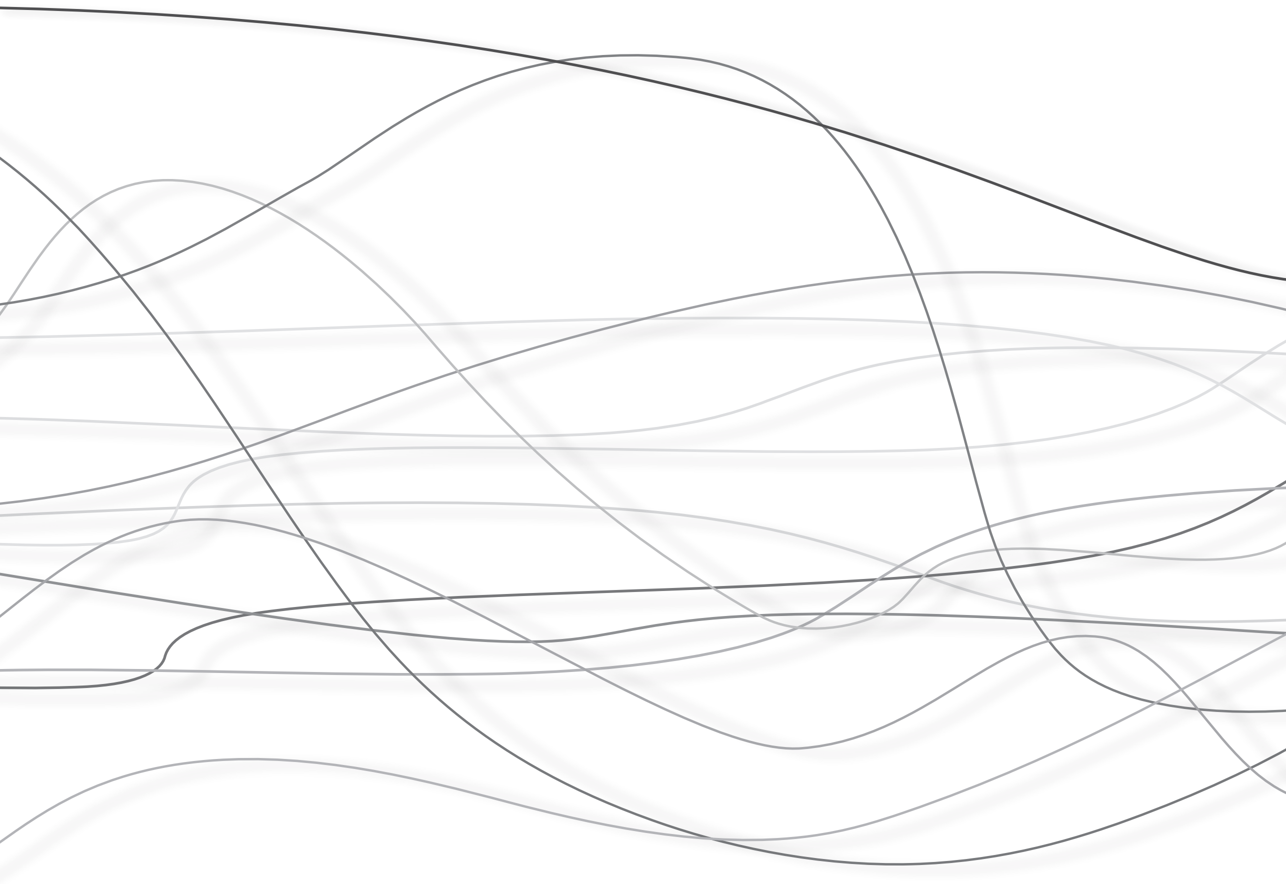

Chapter 2

Individual variation in children's READING COMPREHENSION across digital text types

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Individual variation in children's reading comprehension across digital text types

Abstract

The present study examined children's digital text comprehension of various digital text types: linear digital text, digital text with navigable graphical overview, digital text with embedded hyperlinks (hypertext) and hypertext with navigable graphical overview. We investigated to what extent individual variation in children's comprehension could be explained by lexical quality (word decoding & vocabulary), cognitive load factors (i.e., prior knowledge & working memory), text types, and graphical overview. Participants were 93 6^{th}-graders in a within-subjects design. In line with the lexical quality hypothesis, decoding skills and vocabulary were strong predictors of children's digital comprehension scores. The various digital text types did not account for variance in children's digital comprehension. It is concluded that digital texts with basic digital text features and comprehension questions during reading are suitable for primary school children, pending a sufficient level of lexical quality.

Introduction

Children in primary schools read digital text for educational goals, but comprehending nonlinear digital text is essentially different from printed linear text (Mangen, Walgermo, & Brønnick, 2013). Hypertext with embedded hyperlinks is a special form of digital text and may also vary as regards the presence or absence of overviews and hyperlinks. Skilled readers enter a nonlinear digital text with adjusted reading skills (Kumbruck, 1998); they often have a question for which they have already activated their prior knowledge. These skilled readers direct their reading behaviour to answer their question while navigating in a coherent way to prevent disorientation. Therefore, considerable research has emphasized that the reading of digital text with or without embedded hyperlinks and navigable graphical overviews requires adjusted linguistic skills and processing resources in comparison to printed text (Kumbruck, 1998; Mangen, 2008; Mangen et al., 2013; Waniek & Ewald, 2008). In line with the so-called lexical quality hypothesis (Perfetti, 2007), word decoding and vocabulary have been evidenced as predictors of linear reading comprehension. And, in perspective of cognitive load theory, prior knowledge and working memory, can be seen as additional predictors of digital text comprehension (Amadieu, Tricot, & Mariné, 2009; Calisir, Eryazici, & Lehto, 2008; DeStefano & LeFevre, 2007; Kirschner, Kester, & Corbalan, 2011; Zumbach & Mohraz, 2008). It is a well-established fact that children read digital texts with less automatized reading skills and low-prior knowledge (Lawless, Mills, & Brown, 2003; Salmerón & García, 2011). However, it is by no means clear how children's reading comprehension is affected by different digital text types and how individual differences can be explained. Therefore, in the present study we examined children's individual variation in digital text comprehension as a function of lexical quality, prior knowledge and working memory as well as of different digital text types.

Literature Review

Reading digital text with embedded hyperlinks or graphical overviews is different from reading linear digital text without hyperlinks (Kumbruck, 1998; Mangen et al., 2013; Waniek, 2012). Digital texts with hyperlinks give the reader flexibility in acquiring the text material in an adaptive way to the reader's goals. However, the drawback of this flexibility is the larger risk of getting disorientated, because multiple paths connect different text sections, and the reader has to determine a coherent reading path during reading (Amadieu, Tricot, & Mariné, 2010; DeStefano & LeFevre, 2007; Foltz, 1996; Salmerón, Cañas, Kintsch, & Fajardo, 2005). Empirical research has generally shown the enhanced difficulty

2

of comprehending and learning from digital text (cf. Bezdan, Kester, & Kirschner, 2013; DeStefano & LeFevre, 2007; Wells & McCrory, 2011).

There is a substantial body of evidence that hierarchically structured digital texts may reduce disorientation, dependent on the complexity of the content, because clear structure supports a coherent reading order (Waniek, 2012). When there is global coherence in the digital text, the reader needs to make fewer inferences to understand the meaning of the text (Zumbach, 2006; Zumbach & Mohraz, 2008). In line with this, Calisir et al. (2008) as well as Amadieu et al. (2010) showed that reading comprehension of skilled readers in hierarchical digital text was higher than their reading comprehension of linear text or networked digital text, respectively.

Structural features in digital text such as underlined or highlighted content words as hyperlinks and navigable graphical overviews support the reader to grasp the digital text structure (Bezdan et al., 2013; Jin, 2013; Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009; Vörös, Rouet, & Pléh, 2011; Waniek, 2012). In a study with 13-year-olds, it was shown that these students seem to form a better situation model when reading hypertexts with or without overview in comparison to linear digital texts (Klois, Segers, & Verhoeven, 2013). And, research with undergraduate students as well as middle school students has shown that clear structured graphical overviews may help the reader to build a macrostructure of the digital text, enhance a coherent navigation pattern (i.e., reduced working memory demands for navigation and decision-making) and comprehension (Amadieu et al., 2010; Naumann, Richter, Flender, Christmann, & Groeben, 2007; Potelle & Rouet, 2003; Salmerón et al., 2009; Salmerón & García, 2011). Thus, there seems to be a substantial body of evidence that overviews may enhance explicit awareness about the text structure and facilitate the construction of a situation model, since it can be assumed that overviews help readers to invoke relevant background information and schemas (Naumann et al., 2007; Salmerón & García, 2012; Vörös et al., 2011). However, overviews can restrain comprehension when the navigation path in digital text is restricted (Bezdan et al., 2013). In general, minimally structured overviews that support low-prior knowledge readers to navigate through the digital text and to construct their own organization of the information have produced the best recall results, because they provide cohesion, which helps to create a coherent mental representation of the text (Amadieu, Van Gog, Paas, Tricot, & Mariné, 2009; Dee-Lucas & Larkin, 1995).

Individual Differences in Digital Text Comprehension

Reading comprehension of linear text includes many different cognitive processes from bottom-up processes (word identification & vocabulary knowledge) to top-down comprehension processes (inference making) (Hersch & Andrews, 2011; Perfetti, Landi & Oakhill, 2005; Verhoeven & Graesser, 2008). Studies on the individual variation in linear text comprehension with children showed that reading comprehension is largely predicted by the quality of lexical representations as indicated by high levels of word decoding skills and vocabulary knowledge (Hersch & Andrews, 2011; Perfetti, 2007; Richter, Isberner, Naumann, & Neeb, 2013). These differences in lexical representations of words may also explain individual differences in digital text comprehension.

Reading digital text seems to demand additional cognitive activities from the reader, because drawing inferences for higher levels of comprehension and preventing disorientation during reading requires cognitive resources of the working memory (DeStefano & LeFevre, 2007; Wenger & Payne, 1996). Research of digital text comprehension must necessarily consider the matter of prior knowledge and working memory (Amadieu et al., 2009; Baddeley, 2012; Naumann, Richter, Christmann, & Groeben, 2008; Ozuru, Dempsey, & McNamara, 2009) and particularly with regard to children. Salmerón and García (2011; 2012) found that children's digital text reading, especially without graphical overview, may easily lead to cognitive overload and comprehension problems, because less skilled readers may not be able to navigate in a coherent and meaningful way through the digital text. The flexibility in reading order of a digital text thus enhances cognitive load (Bezdan et al., 2013; Kirschner, Kester, & Corbalan, 2011; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Sweller, 2005; Zumbach & Mohraz, 2008), but overviews may help the reader to grasp the macrostructure of the text in perspective of selecting a coherent navigation pattern and reducing cognitive load (DeStefano & LeFevre, 2007; Salmerón et al., 2009). Indeed, Naumann et al. (2007) found that hyperlinks and overviews are beneficial for navigation and improve text comprehension in low skill learners. Salmerón and García (2012) found similar effects for readers with low comprehension and low sustained attention, but also that hypertext structural features demand higher visuo-spatial skills of 6th-grade students. In other words, the digital text features may change the reading behaviour of the reader (Klois et al., 2013) and therefore reading skills, level of prior knowledge and working memory capacity should all come into play when investigating children's digital text comprehension.

The Present Study

Most researchers of digital text comprehension so far, however, have examined digital text comprehension of skilled readers in complex learning scenarios, with demanding comprehension or learning tasks, but the findings are equivocal for children's reading comprehension tasks. Research on digital text comprehension has primarily focused on cognitive load in skilled readers with low-prior knowledge but without taking into account the role of lexical quality and without studying less skilled readers. Making inferences may consume cognitive resources of the limited working memory of less skilled readers, without appropriate prior knowledge, resulting in lower comprehension (Nation, 2005). A meta-analysis by Carretti, Borella, Cornoldi, and De Beni (2009) indeed revealed that deficits in reading comprehension could be partly attributed to a shortage of the working memory control mechanisms. The degree to which the results of adults' digital text reading comprehension research can be generalized to children's digital text comprehension is limited and should be viewed with caution, because of differences in the comprehension task demands.

Assignments for children should consider task demands and permit the reader to efficiently use their limited cognitive capacity (Paas et al., 2003). In many studies, reading comprehension was measured with recall tests and multiple choice (MC) questions after reading the text, which are in fact tests of memory (Amadieu et al., 2010; Vörös et al., 2011). These comprehension tests *after* reading appear to be appropriate for adults and skilled readers with a certain amount of prior knowledge. However, the effort to memorize during reading can interfere with text comprehension (Andreassen & Bråten, 2010; Smith, 1975). It might be more appropriate for children to reduce the influence of memory as well as prior knowledge and to give the questions *during* reading of the text to measure actual comprehension and not recall. Indeed, Ozuru, Best, Bell, Witherspoon, and McNamara (2007) showed a decline in the relationship between prior knowledge and comprehension when participants were allowed to answer the questions during reading.

In the present study, we investigated children's differences in reading comprehension between four digital text types in which the absence and presence of overviews and hyperlinks was systematically varied: linear digital text (LDT), digital text with navigable graphical overview (DTO), digital text with embedded hyperlinks (HT) and hypertext with navigable graphical overview (HTO). Children from 6th grade of primary schools were tested in a within-subjects design. They were tested for reading comprehension while reading the four text types with four random topics in a random order with comprehension questions being available during reading. We investigated the following research questions:

Q1: To what extent can the individual variation in reading comprehension in the four digital text conditions be explained from the lexical quality hypothesis, prior knowledge and working memory, as well as text type and overviews?

Q2: Do digital text type and graphical overviews moderate the relation between individual characteristics and reading comprehension?

We expected individual child characteristics, text type and overviews to each account for significant variance in children's digital text comprehension. As such, we hypothesized that decoding and vocabulary would predict children's reading comprehension based on the lexical quality hypothesis. In line with the cognitive load theory, we also assumed prior knowledge and working memory to predict children's digital text comprehension. Regarding the digital text type we hypothesized that hyperlinks would have a negative effect on comprehension, whereas graphical and navigable overviews would facilitate text comprehension. Finally, we expected the influence of individual characteristics to diminish when the texts contained overviews, whereas they would be larger when the text contained hyperlinks.

Method

Participants

In the present study, 106 children from five 6^{th}-grade classes (54 girls, 52 boys) with a mean age of 11 years, 8 month (*SD* = 4.98 month) participated. Two Dutch primary schools with an average social economic status and a low percentage of children from ethnic minorities in the southern part of the Netherlands were recruited by letter. Thirteen children were excluded, because of incomplete data or absence during data collection. The final sample of the present study included 93 6^{th}-grade children (51 girls, 42 boys) with a mean age of 11 years, 7 months (*SD* = 5.16 months; age range: 10 year, 7 month – 12 years, 6 month). Raven's Standard Progressive Matrices (SPM; Raven, Raven, & Court, 2003) was assessed to measure children's general mental ability as control variable with *M* = 43.64 (*SD* = 6.25) as group average (50^{th} percentile), indicating a sample with average and normal general mental ability. All children were tested in Dutch. Furthermore, children's computer literacy was examined with a questionnaire including 7 items with a total score of 26 (Citogroep, http://toetswijzer.kennisnet.nl). The computer literacy questionnaire revealed that children were experienced in working with a computer and on the Internet (*M* = 21.61; *SD* = 2.34). The children were unfamiliar with the purpose of the experiment. The primary caregivers provided their informed written consent.

Materials

Text materials. Four digital text types were used, see Klois et al. (2013). Children read four Dutch digital texts, presented in a random order and counterbalanced with four different topics (*M* = 974 words, *SD* = 36.21). To accomplish a hierarchical structure of the texts, the topic was introduced on the first page, followed by three main chapters and two subchapters per main chapter for each text. The linear digital text (LDT) contained forward and backward buttons, so that the children could navigate between the pages. The digital text with navigable graphical overview (DTO) contained the linear digital text supplemented with a hierarchical and navigable overview at the top of each page. The children had to click on one of the 10 hyperlinks in the overview to navigate between the pages. Therefore, this digital text type is *nonlinear* because children choose their reading order by clicking on the hyperlinks in the navigable overview in a non-restricted individual order. The hypertext (HT) contained the linear digital text and 10 hyperlinks in total that were identical to the keywords of the overview of the DTO. The hyperlinks were standard blue, underlined and changed from blue to gray after clicking on them. The hypertext with navigable graphical overview (HTO) contained the hypertext supplemented by the same hierarchically structured graphical and navigable overview as in the DTO. Therefore, the HTO contained 20 links in total. In the HT and HTO text, the hyperlinks per page linked to all possible pages of the next level of the hierarchy. Therefore, per page, a number of 2 or 3 hyperlinks were embedded.

To ensure an experimental within-subjects design, all children read all four digital text types in a random order. In addition, the four digital text types were designed in four different text topics in Dutch (Oceania, Russia, South America, South Africa; The Reader's Digest, 2002) of informative geography textbooks written for this age, to exclude an effect of text topic: 4 text types × 4 topics, resulting in 16 text materials. The four digital text types (LDT, DTO, HT, HTO) and the four text topics were counterbalanced and presented in a random order to reduce order effects.

Reading comprehension. To assess the children's reading comprehension of the four texts, 20 MC questions for each topic (Oceania, Russia, South America, South Africa), with four possible answers were used; see Klois et al. (2013). The questions were both explicit comprehension questions and implicit comprehension questions within the scope of the relevant text (example of an explicit question: "The Kagu in Oceania belongs to which species group? (a) Mammals, (b) Birds, (c) Reptiles, (d) Insects"; example of an implicit question: "Why is a tree in Oceania called breadfruit tree? (a) Because the fruits are the same for the people in Oceania as fresh bread is for us, (b) Because the fruit tastes similar to bread, (c) Because the fruits look like cinnamon buns (d) Because many birds brood in the trees) (Klois et al., 2013). Per text topic, the comprehension questions were printed out on paper to ensure that children can read the whole text on the computer screen.

Linguistic measures. To assess the children's *word decoding* skills, the one minute test was conducted (Een Minuut Test; Brus & Voeten, 1973). The test is assessed individually. The participant had to decode printed words as fast as possible in one minute. The test is suitable for children between 7 and 12 years. It contains two similar test sets, at which the situational arrangement of words is randomized in version A and version B. On each set, 116 words are presented, which increase in difficulty. The total score is calculated by counting the words that were read correctly within one minute.

The children's *vocabulary* was assessed with a vocabulary test, consisting of 36 items (Woordenschattest; Aarnoutse, 1989). During the test, the participant has to choose the word that is closest in meaning to the word in a sentence offered. The participant can choose from four alternative explanations. The test starts with three sample items and the difficulty of the test is not ascending.

Cognitive measure. The children's *working memory span* was assessed with the Digit Span test from the WISC-III-NL (Wechsler Intelligence Scale for Children-III; Kaldenbach, 2010; Kort et al., 2005). The Digit Span test is a subtest of the WISC, in which the participant has to hold a string of numbers in working memory, while reproducing the numbers in the same order (digit span forward) or backward (digit span backward). The span of digits increases from two to seven during the test phase. The test starts with the Digit Span Forward, which contains eight digit spans and continues with the digit span backward, which contains seven digit spans, increasing in difficulty, hence, the participant has to remember one digit more during the test. The test stops when the first and second trial of one digit span is wrong. Total test scores were calculated from the digit span forward and digit span backward scores, the maximum test score was 30.

Prior knowledge. Pretest questions were extracted from the MC questions of the four texts, to assess the amount of prior knowledge of the children. Four MC questions per text, two detail comprehension questions and two global comprehension questions, were chosen at random. In total, the prior knowledge test contained 16 MC questions. It should be noted that the prior knowledge questions accounted for 20% of the actual comprehension measures in the experiment.

Procedure

First, the children were tested individually on word decoding (one- minute test) and working memory span; this took approximately 15 minutes. Children were next tested in their classes for the pretest MC questions and vocabulary test; this took approximately 40 minutes. Due to the time delay of two months between the pretest of the child characteristics and the actual experiment, an effect of the prior knowledge questions and the comprehension measures of the experiment can be excluded, especially since no feedback was given.

The experimental phase started two months later. The experiment was conducted in four lessons (45min) distributed over four days. Children were distributed at random in a within-subjects design over the four text types and four topics within these four lessons. Thus, children read all four text types but about different topics, in a randomized block design. For example, one child read in the LDT type about Russia, in DTO about Oceania, in HT about South America and in HTO about South Africa. Another child read the same text types but about other topics: in LDT about South Africa, in DTO about Russia, in HT about Oceania and in HTO about South America. It was controlled that all text types and topics appeared in the same amount. During the four reading sessions in the computer classroom, the children received written instructions, which were further clarified via oral explanation. They were instructed to read the text carefully and to answer the 20 MC questions about the text during or after reading. Children read the texts in full screen mode and there was no time limit. The children had to click on a ‘finished reading’-button on the last page of the LDT version and on the introduction page of the DTO, HT and HTO version, after finishing reading and answering all questions.

Results

The pretest scores for the children’s prior knowledge as measured using a subset of the MC questions (16 questions; $M_{\text{correct}} = 5.68$, $SD = 2.11$; $M_{\text{chance-level}} = 4.00$) confirmed that they were low-prior knowledge readers of the four geography topics and had an average normal general mental ability ($M = 43.64$; $SD = 6.25$). Table 1 presents the descriptive statistics as means and standard deviations of the children’s linguistic as well as cognitive predictors as well as reading comprehension scores in the four digital text conditions.

We addressed the universal contribution of lexical quality predictors, working memory and prior knowledge as well as text type and the presence or absence of an overview to the reading comprehension scores. First, Pearson’s correlations were computed (see Table 1). The predictors that were next included in the regression models were centred to control for multicollinearity.

One multiple hierarchical regression analysis was run to examine which of the individual predictors contributed to the reading comprehension scores and to examine the contributions of text type and overviews. The two categorical

Table 1 Pearson Correlations and Descriptive Statistics Among Word Decoding, Vocabulary, Prior Knowledge, Working Memory and the Four Digital Text Types.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Word decoding	-							
2. Vocabulary	.220*	-						
3. Prior knowledge	.064	.371**	-					
4. Working memory	.423**	.213*	.102	-				
5. Reading comprehension LDT	.380**	.553**	.426**	.398**	-			
6. Reading comprehension DTO	.560**	.453**	.166	.360**	.472**	-		
7. Reading comprehension HT	.538**	.427**	.260*	.425**	.512**	.457**	-	
8. Reading comprehension HTO	.428**	.578**	.237*	.274**	.521**	.499**	.465**	-
M	75.30	28.57	5.68	12.92	12.96	12.52	12.20	12.26
SD	14.73	4.50	2.11	2.60	3.50	3.19	3.84	3.79

$^{**}p < .01$; $^{*}p < .05$

2

variables Text Type (0 = text without embedded hyperlinks, 1 = hypertext) and Overview (0 = no overview, 1 = overview) coded as dummies. The children's reading comprehension scores was the dependent variable in this regression

Table 2 Hierarchical Multiple Regression Analyses with Word Decoding, Vocabulary, Prior Knowledge, Working Memory as well as Text Type and Overviews as Predictors of Reading Comprehension.

Predictor	**ΔR^2**	**β**
Step 1	.69**	
Word decoding		.44**
Vocabulary		.46**
Prior knowledge		.15**
Working memory		.13**
Text type		.00
Overview		.00
Text type * Overview		.00
R^2adj	.69**	
Step 2	.00	
Word decoding		.44**
Vocabulary		.46**
Prior knowledge		.15*
Working memory		.13*
Text type		.00
Overview		.00
Text type * Overview		.00
Text type * Word decoding		.00
Text type * Vocabulary		.00
Text type * Prior knowledge		.00
Text type * Working memory		.00
Overview * Word decoding		.00
Overview * Vocabulary		.00
Overview * Prior knowledge		.00
Overview * Working memory		.00
R^2adj	.68	

**$p < .01$; *$p < .05$

analysis. In Step 1, word decoding, vocabulary, prior knowledge, working memory, text type and overview were entered (see Table 2). In Step 2 the interaction between each of the dummy variables and the individual child characteristics was added. Table 2 shows a summary of the results of the multiple regression. In summary, word decoding, vocabulary, and working memory were robust predictors in the first model (Step 1) of children's reading comprehension disregarding the type of text or the presence or absence of an overview (all *ps* < .05) and accounted for 68.7% of the total variance. Neither the interaction of text type and overview nor the interactions of the categorical variables with the individual child characteristics had an effect above and beyond the effects of the individual linguistic and cognitive child characteristics in the second model.

Discussion

This study aimed to shed light on the role of children's individual variation in digital text comprehension as a function of presence or absence of hyperlinks and overviews, embedded in the frameworks of lexical quality hypothesis and cognitive load. Children in the present study received conceptual comprehension questions and read as well as answered the comprehension questions during reading.

First, we explored the relative importance of individual characteristics, text type and graphical overviews in children's digital comprehension. In line with the lexical quality hypothesis, we found, as expected, that word decoding skills and vocabulary knowledge predicted children's digital text comprehension. These findings correspond to previous findings related to reading comprehension of linear text (Perfetti, 2007), which gives rise to the generalizability of this hypothesis towards digital text comprehension. Our results also indicate that working memory predicted children's reading comprehension. We expected that the influence of the individual characteristics might diminish when the text contained overviews, and might be larger when the text contained hyperlinks. The results revealed no influence of the graphical and navigable overview, as well as the hyperlinks that were the same key words as in the overview on reading comprehension.

Second, with respect to the individual child characteristics, we expected that cognitive load might be reduced by the availability of hyperlinks and overviews, which would lower the predictive power of prior knowledge and working memory. No interactions were found between the individual characteristics and hyperlinks or overviews on children's digital text comprehension. We can assume that simple hierarchical overviews and appropriate hyperlinks that reflect the conceptual model of the text, do not disadvantage digital text comprehension (Jin, 2013; Salmerón & García, 2012; Wenger & Payne, 1996). The basic digital configuration of the four texts as well as the comprehension task did not interfere with children's comprehension. Positive influences of graphical overviews, being found in a previous study in which children received questions *after* they read the text (Klois et al., 2013), were probably overruled by the fact that in the present study the questions were available *during* reading of the text. In essence, we might assume that the strict and clear hierarchical design of the hypertext with basic digital configurations positively influenced children's structural understanding of the text and supported children's reading comprehension by means of selecting an appropriate reading path, in such a way that their comprehension was equal to that of reading a linear digital text.

The present study has some limitations. To examine the cognitive load theory more thoroughly, mental load should be measured direct through self-report questions, physiological tasks or dual-tasks (Paas et al., 2003). Cognitive load during reading is a crucial and a major factor for comprehension failures in digital text with complex comprehension tasks (Bezdan et al., 2013). In complex digital texts, the load on the operating resources of the working memory consequently should increase, possibly impairing children's reading comprehension (DeStefano & LeFevre, 2007). Furthermore, the two-by-two design should be considered with some caution, as the overview presented in above the linear text, had clickable hyperlinks. Children thus could navigate the text in a non-linear way. In a previous study, we, however, evidenced that children tend to read this text linearly (Klois et al., 2013).

Future research should focus more on the navigational pattern in children's reading comprehension. It would be interesting to examine differences between the four digital texts based on navigational pattern and time limitation, which we did not measure in the present study, and consider larger hypertexts that are not necessarily hierarchically structured. It would also be interesting to examine the effect of having the questions together with the text versus answering them afterwards. There are some indications that the former condition may guide the children and support a coherent reading order in digital text (Salmerón et al., 2005). But one also may assume that they would evoke a more strategic way of reading, not leading to a sound situation model. More advanced methodologies as eye-tracking, could also be used to focus more on the children's reading efficacy when reading digital text compared to linear digital text. Especially, gaze data and fixation times could shed light on the interplay between individual differences, as the cognitive characteristics of the reader, the reader's reading skills and reading comprehension (Dyson & Haselgrove, 2002; Salmerón et al., 2009).

To conclude, our results show that digital text reading can be introduced at schools at an early point in time of the school curriculum. In essence, as soon as children already have developed appropriate lexical quality they can be sensitized for the 21st century skills with basic digital text and simple comprehension tasks.

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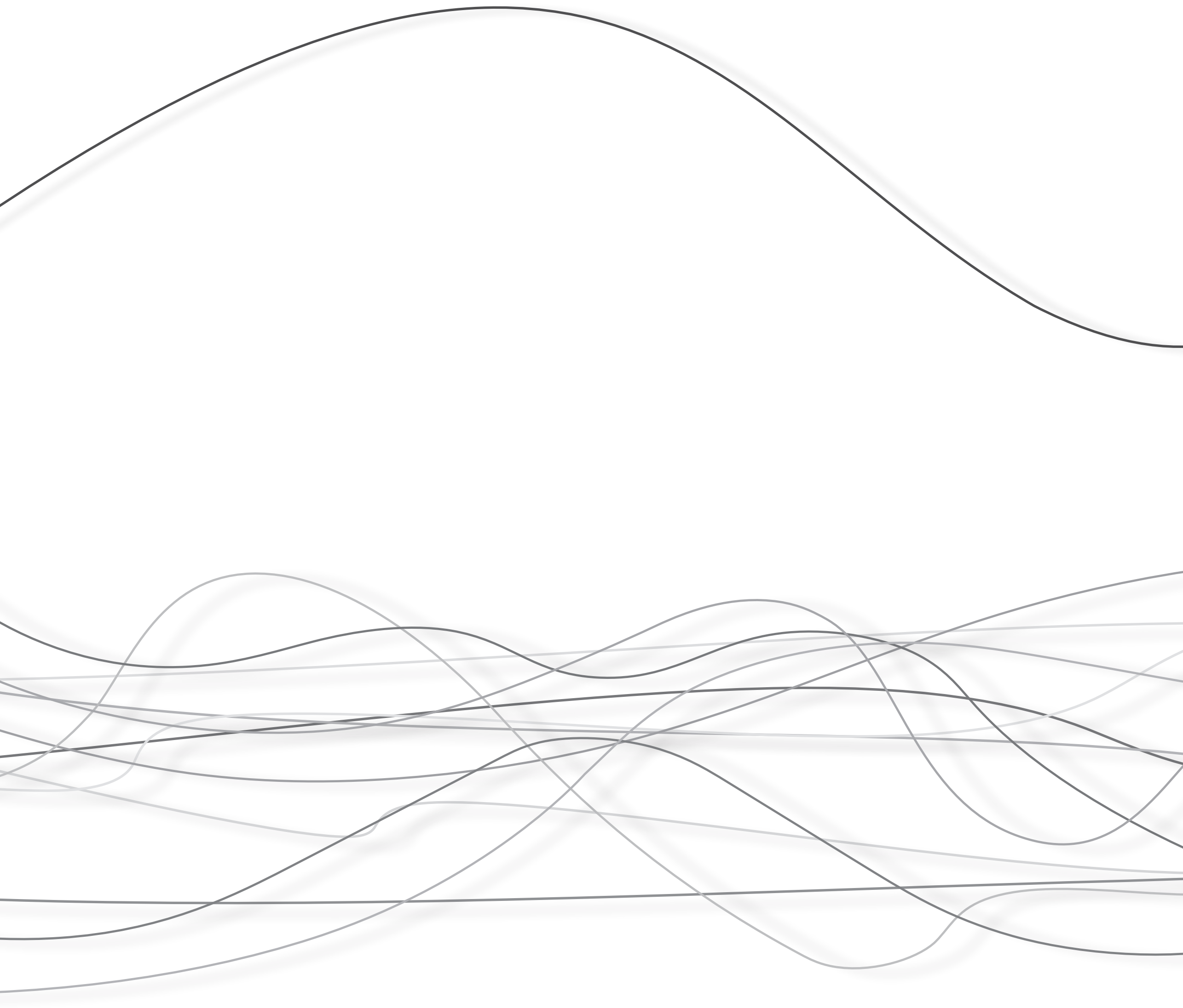

Chapter 3

Quality of children's KNOWLEDGE REPRESENTATIONS in digital text comprehension: Evidence from pathfinder networks

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Abstract

Children in primary school read digital texts for school purposes while current research has shown that forming a coherent knowledge structure of such texts is challenging. We compared the quality of ninety 6th grade children's knowledge structures after the reading of four different digital text types: linear digital text, digital text with overview, hypertext, and hypertext with overview. Psychometric pathfinder network scaling of relatedness ratings were used to assess children's knowledge structures. For each text type, we compared the similarity of the children's knowledge structures to both a sequential (linear) model and a qualitatively richer expert model. Moreover, we examined to what extent similarity of children's knowledge structures with the two models predicts reading comprehension. Children's knowledge structures were overall more similar to the sequential model. Although similarity with the sequential model predicted reading comprehension in all four text types, similarity with the expert model accounted for additional reading comprehension variance in hypertext and hypertext with overview. Prior knowledge accounted for the variance in comprehension in linear digital text, even after controlling for similarity with the models. Evidence suggests that reading hypertext may foster deeper comprehension given that hypertext comprehension was also predicted by similarity with an expert-like situation model.

Introduction

Digital texts have an ubiquitous presence in primary schools. Many of these digital texts are complex and primarily attuned to skilled readers, requiring the construction of a coherent knowledge representation using embedded hyperlinks and navigable (graphical) overviews (DeStefano & LeFevre, 2007; Jin, 2013). It is by no means clear if children accomplish high-quality or sufficient knowledge representations after reading digital text. Therefore, in the present study we aimed to examine the quality of children's knowledge structures across different digital text types, while using the psychometric network scaling pathfinder technique (Clariana, 2010; Clariana & Wallace, 2009; Ifenthalter & Pirnay-Dummer, 2014) to compare children's knowledge structures with a sequential knowledge representation, on the one hand, and a qualitative richer adult expert knowledge representation, on the other hand.

Digital Text Comprehension Research

Research of digital text comprehension with adult readers evidenced the challenges and difficulties in building a coherent representation of nonlinear digital text (DeStefano & LeFevre, 2007). In linear text comprehension research, it is assumed that readers build qualitatively different knowledge structures during the comprehension process (Johnson-Laird, 1983) based on both bottom-up (driven by the explicit text) and top-down processes (general knowledge and inferences) (Graesser, 2008; Graesser & McNamara, 2011; Kintsch, 2005; Kintsch & Van Dijk, 1978; Verhoeven & Graesser, 2008). It is also assumed that knowledge structures are stored as networks of concepts and are upgraded with new information being integrated through inferences and reorganized in relevant (prior-knowledge) networks (Clariana, 2010; Goldsmith, Johnson, & Acton, 1991; Jonassen, 1993; Trumpower, Sharara, & Goldsmith, 2010). According to the interactive and cyclical pattern of the Construction-Integration model (Kintsch, 2005), a reader forms a *text base* model (bottom-up) of the text in the construction process. The formation of a text base is sequential in nature because the reader processes the content of the text linearly (Larkin & Simon, 1987). In the integration process, a reader makes inferences with the text base and his or her prior knowledge on the fly to build a *situation model* (top-down) of what the text is about (Kintsch, 2005; Zwaan & Radvansky, 1998). In this latter process, it can be assumed that the reader activates prior knowledge (top-down) to draw inferences in order to accomplish coherent knowledge structures (Wolfe & Mienko, 2007; Wolfe & Woodwyk, 2010; Zwaan, 1998).

Previous research of adult's digital text comprehension showed that the reader must control and determine a coherent reading order and flexibly reconstruct and integrate prior knowledge to accomplish a coherent situation model compared to reading linear text. Thus, the quality of children's knowledge structures in digital text is facilitated by the coherence of the reading order and the amount of prior knowledge that a reader has (McNamara, Kintsch, Songer, & Kintsch, 1996; Tapiero, 2007). It has been found that rather than 'reading', the digital text features demand readers to 'browse' nonlinearly through the sections, jumping from one text section to another, based on their prior knowledge and the facility of their comprehension process. This demands additional top-down processes and self-regulated metacognitive skills as monitoring, planning, and evaluating from the reader during reading to prevent disorientation (Azevedo & Cromley, 2004; DeStefano & LeFevre, 2007). This active reading process increases the cognitive load and may degrade their comprehension of digital text (DeStefano & LeFevre, 2007). Otter and Johnson (2000) directly considered the accuracy of readers' situation models in digital text and compared these to disorientation. Their results indicated that associative hyperlinks may induce disorientation due to high cognitive load in hypertext reading. To overcome cognitive overload, it can be assumed that the reading behavior in digital text has to be active and coherent, which may in fact be beneficial for drawing inferences and hence, the building of a coherent knowledge structure (Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009; Waniek, Brunstein, Naumann, & Krems, 2003).

In digital text, the text structure is expressed by means of textual features including hyperlinks and overviews that permit flexibility in reading order (Salmerón & García 2011; 2012; Waniek, 2012). And these features can, to some extent, support macro-level structure understanding, support coherence, and prevent the reader from becoming disoriented (Jin, 2013; Madrid, Van Oostendorp, & Melguizo, 2009; Meyer, Ray, & Middlemiss, 2012; Payne & Reader, 2006; Salmerón & García, 2011, 2012). Such features support the building of a rich and coherent knowledge structure (Clariana, 2010; Ritchey, Schuster, & Allen, 2008; Salmerón et al., 2009; Waniek, 2012; Waniek et al., 2003). However, Bezdan, Kester, and Kirschner (2013) showed that the continuous use of overviews may disadvantage learning on the micro-level of the comprehension process, often being reflected in qualitative differences in the readers' knowledge structures.

Research on children's digital text comprehension and the quality of children's knowledge structures is limited. Previous studies have examined children's navigation strategies in digital text and focused on strategy training to overcome high cognitive load and disorientation in digital text comprehension (Coiro & Dobler, 2007; Salmerón & García, 2011; 2012). Regarding children's navigation strategies, two studies indicated that children and adolescents use the same navigational patterns and that reading skills predicted the use of hyperlink selection but not the use of overviews (Lawless, Mills, & Brown, 2003; Salmerón & García, 2012). Rouet and Coutelet (2008) examined children's search strategies in digital text and indicated that older children search faster and used more top-down strategies based on the use of structural organizers. Coiro and Dobler (2007) found that digital text features prompt self-directed situation model construction via prior knowledge, inferential reasoning, and self-regulated reading processes for sixth-graders searching for information in digital text (Coiro & Dobler, 2007). On the other hand, Klois, Segers, and Verhoeven (2013) examined knowledge acquisition with the aid of mind maps in seventh-grade children and the relation between navigation pattern and construction of situation models. Their results suggested that hyperlinks in digital text may in fact foster a deeper level of learning in children. Analyses of the children's mind maps showed richer situation models in hypertext compared to texts without hyperlinks.

To sum up, research points to the difficulty of organizing knowledge structures when reading digital text especially due to high cognitive load and disorientation. Research on digital text comprehension with children, however, is quite limited and has primarily focused on strategy training. It is by no means clear how children structure their knowledge representations across various types of digital texts; describing these knowledge structures can help explain and account for comprehension difficulties.

Assessment of Knowledge Structures

Measuring the structure of reader's knowledge representations is complicated since directly tapping a text base and a situation model is challenging. A critical question arises of how the organizational properties of comprehension can be captured by product and process data (Diekhoff, 1983; Fenker, 1975; Gonzalvo, Cañas, & Bajo, 1994). Magliano, Millis, Ozuru, and McNamara (2007) evaluated reading comprehension assessment tools in a multidimensional framework, focusing on the comprehension process, products, activities, ability level of the reader, as well as types of texts. To gain insight into reader's knowledge structures, researchers of linear text comprehension have used *process* methods, such as think-aloud protocols, and *product* methods, such as multiple choice questions and essays (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012; Leopold & Leutner, 2012; Leopold, Sumfleth, & Leutner, 2013). However, each of these methods has shortcomings: Think-aloud protocols do not give insight into the quality and structure of the reader's knowledge representation, answering of multiple choice questions is highly dependent on general reasoning, and the quality of an essay depends at least partly on the writing skills of the reader (Eason, Goldberg, Young, Geist, & Cutting, 2012). Mind maps can be seen as a useful alternative method for eliciting knowledge structures (Clariana, 2010; Gonzalvo et al., 1994). However, drawing a complete and satisfactory mind map requires training and practice and the objective scoring of mind maps has proven to be difficult (Clariana, Koul, & Salehi, 2006).

A promising method to examine the effect of different digital text types on the quality of children's knowledge structures is a relatedness judgment task that is analyzed using the model-based pathfinder approach (Clariana & Wallace, 2009; Ifenthalter & Pirnay-Dummer, 2014). Here, participants have to give a direct numerical rating of degree of relatedness between pairs of concepts on a scale varying from 'not related' to 'highly related'. A pathfinder scaling technique transforms these judgments into a single network of these concepts (reflecting the knowledge structures of a reader). An advantage of the relatedness judgment task is that individual knowledge structures can be compared to other text models, for example sequential text-based models and also to expert knowledge structures of the same text (Clariana, 2010; Clariana & Wallace, 2009; Trumpower et al., 2010).

The pathfinder approach, which is a cognitive research tool and a graph theoretic approach, can capture structural representations and reveal the organizational property of knowledge (Clariana & Wallace, 2007; Johnson, Goldsmith, & Teague, 1994). An advantage of the structural assessment technique is that a reader's structural knowledge can be referenced relative to an average network of experts (Goldsmith et al., 1991; Gonzalvo et al., 1994; Koul, Clariana, & Salehi, 2005). Gonzalvo et al. (1994) validated comparisons between student and expert similarity measures with pathfinder. This assessment technique is a three stage process (Goldsmith et al., 1991): (1) knowledge elicitation (i.e., card sorting, word associations, relatedness-judgment rating), (2) knowledge representation (trees, hierarchical clustering, networks, pathfinder nets), (3) knowledge comparison (expert, novices, qualitative graph comparison).

For knowledge representation, the proximity matrix itself represents raw proximities and is assumed to be 'noisy' (Goldsmith et al., 1991). The KNOT scaling procedure (Schvaneveldt, 1990) reduces the noise and reflects the underlying organization as networks capturing local relationships (Schvaneveldt, 1990). The pathfinder scaling algorithm transforms individual's matrixes of relationship data into network structures. Pathfinder associative networks are two-dimensional graphic networks that can be used to model knowledge and to discriminate different levels of knowledge (McDonald, Paap, & McDonald, 1990; Trumpower et al., 2010). It is assumed that the relatedness ratings between pairs of concepts provide an estimate of strength of association between concepts in memory, known as proximity data (Goldsmith et al., 1991). These pathfinder nets represent concepts (words) as nodes and relationships as links between the nodes, and visually resemble concept maps and mind maps (Schvaneveldt, 1990). The algorithm is a data reduction approach that searches for the shortest path between concepts, which is purported to be the most salient concept associations.

The Present Study

In the present study, we determined the quality of children's knowledge structures of diverse digital text types and compared these to a sequential model as well as to an expert model. In this study children's situation models were operationalized as structural knowledge representations with a relatedness-judgment task, the relatedness-judgments being analyzed with the pathfinder technique to knowledge structures as *pathfinder networks (nets)* (Clariana & Wallace, 2009; Ifenthalter & Pirnay-Dummer, 2014). These pathfinder nets can be seen as semantic maps that reflect semantic distances between concepts by calculating relatedness coefficients and mapping those associations (Gonzalvo et al., 1994; Jonassen, 1993). Accordingly, it is assumed that these networks directly tap the structure of children's knowledge representations, leading to the following research questions in the present study:

3

Q1: How do children structure their knowledge representations across different digital text types?

Q2: To what extent does similarity of children's knowledge representations with a sequential and expert model predict their reading comprehension in these different digital text types?

With respect to the first research question, it can be assumed that digital text may very well affect the interplay between bottom-up and top-down processes in building a situation model of the text, which might be reflected in structural and qualitative differences of children's knowledge structures. Also, it can be assumed that children with low-prior knowledge can or cannot effectively use organizational signs as hyperlinks as well as navigable overviews during reading, which could be reflected in qualitative differences of their knowledge structures in different text types (Bezdan et al., 2013). Accordingly, we hypothesized that reading linear digital text would yield primarily sequential knowledge structures whereas reading hypertext would give more room for the construction of richer and expert-like knowledge structures. Furthermore, we expected that the presence of overviews in digital text comprehension would also contribute to the construction of more expert-like knowledge structures.

Regarding the second research question, we expected a relation between the quality of children's knowledge structures (sequential versus expert model) and their reading comprehension scores. We hypothesized that similarity with the sequential model predicts reading comprehension in all four text types. In addition, we expect that similarity with the expert model predicts children's reading comprehension over and above similarity with the sequential model only in hypertexts or texts with a hierarchical overview.

Method

Participants

One hundred six 6th-grade children (54 girls, 52 boys) with a mean age of 11 years and 8 month (*SD* = 4.98) from five classes of two primary schools in the Netherlands participated. We recruited the schools by letter. Thirteen children were excluded, because of incomplete data. Three other children were excluded, as their prior knowledge of the four text topics was very high (i.e., *M* = 10 and exceeded 2 *SD*), and the focus of the present study was on low or no prior knowledge readers. In the final analysis, 90 children were included from 6th-grade (51 girls, 39 boys) with a mean age of 11 years and 7 month (*SD* = 5.23 months, range: 10 years and 7 month – 12 years and 6 month). The primary caregivers provided their informed written consent. The children were unfamiliar with the purpose of the experiment.

Materials

Text materials. All children read four digital text types: linear digital text (LDT), digital text with overview (DTO), hypertext (HT), and hypertext with overview (HTO). The LDT condition contained forward and backward buttons so that the children could navigate between the pages. The DTO condition contained the linear digital text supplemented with a hierarchical and navigable overview at the top of each page. The children had to click on one of the ten hyperlinks in the overview to navigate between the pages. The HT condition contained the linear digital text and ten hyperlinks within the text that were identical to the keywords of the overview in the DTO condition. The links were standard blue and underlined; when clicking on the link, it changed from blue to gray. The HTO condition contained the hypertext supplemented by the same hierarchical overview as in the DTO condition. Therefore, the HTO condition contained ten links in the text plus ten links in the overview and hence, twenty links in total. Children read the texts in full screen mode.

To assure a within-subjects design, all participants read at random one of four text topics (Oceania, Russia, South America or South Africa) in the four digital text types. Therefore, 16 text materials were developed (4 text types × 4 topics). These four informative geography texts in Dutch were summarized from textbooks written for this age (The Reader's Digest, 2002). Each text was distributed across 10 pages with 974 words (*SD* = 36.21) in total. To accomplish a hierarchical structure of the texts, the topic was introduced on the first page, followed by three main chapters and two subchapters per main chapter for each text (see also Klois et al., 2013).

Reading comprehension. To assess reading comprehension of the four texts, children had to answer 20 four-choice multiple choice (MC) questions respectively for each text (Klois et al., 2013). The nature of the 20 questions per topic encompassed a mixture of MC questions that aimed to measure the text base and situation model level to the same degree.

Prior knowledge of the topics. To assess the children's amount of prior knowledge of the topics, pretest MC questions were extracted from the 80 MC questions of the four texts. For each text topic, four MC questions were at random chosen. The MC questions encompassed a mixture of questions related to the text base and to the situation model. In total, the prior knowledge test contained 16 MC questions (Klois et al., 2013).

Assessment of knowledge structures. To examine children's knowledge structures of the four text formats, KU-mapper software (Clariana & Wallace, 2009) was used. Based on the assumption that the meaning for a concept can be implicitly measured with the pattern of relationships to other concepts, the KU-mapper measures the children's structural knowledge. The KU-mapper task format was adapted from the relatedness-judgment approach and was designed to integrate with pathfinder Knowledge Network and Orientation Tool software (KNOT; Schvaneveldt, 1990; Version 6.2; available at http://inerlinkinc.net). For the relatedness judgment task, the most important 15 concept terms (in Dutch) for comprehension for each of the four text passages were selected (15 x 4 terms), based on their number of frequency and meaningfulness. The nature of the 15 concept terms for each text passage encompassed a mixture of concepts relevant for the text base and situation model. The children's task was to judge the relatedness of these randomly presented pairs of terms by clicking-on scale varying from unrelated (1) to highly related (9) (see Clariana et al., 2006; Clariana & Wallace, 2009). This rating of degree of relatedness produces a matrix of proximity values for each individual. Each value in the matrix corresponds to the relatedness between a single pair of concepts. A pathfinder scaling algorithm transforms the matrixes of relationship data into network structures for each child for all four text topics.

The instructions on the screen were in Dutch. Via oral explanation, the task was explained to the children and it was stressed that the selection should be based on the first impression of relatedness. The 15 concept terms were displayed on the bottom of the screen, and above the list was a progress indicator that stated "You have (# *count*) comparisons left to make". All possible pairs of concepts were compared to each other with the exception of two same concepts, resulting in n(n-1)/2 distinct pairs of comparisons, in total 15×14/2 = 105.

Sequential model. We used the approach described by Clariana (2010) to convert the four digital text passages into sequential (linear) model from with the aid of the software *ALA-Reader*. *ALA-Reader* was used to convert the 4 sets of 15 concept terms according to their linear sequence in the four text passages directly into proximity raw data files that are then transformed to pathfinder networks and analyzed using pathfinder KNOT software.

Expert model. For each text passage, we calculated an average pathfinder net from the pair-wise relatedness judgment task of four undergraduate university students. Pathfinder analysis requires a benchmark (i.e., expert) set of associations for comparison purposes, but there is not yet an external gold standard in the comprehension and reading intervention research literature for establishing apposite knowledge structure. Teachers as well as university students are often regarded as expert readers in comparison to children. Thus in the present study, university students, who are very experienced in reading digital text were employed as expert readers. The university students received two European credit points for their participation. It should be mentioned that the experts read texts that were suited for grade six, therefore, the experts reported neither comprehension difficulties nor navigation problems. The expert students followed the same instructions as the children and read the texts in the same digital formats. In addition, the university students were informed of the purpose of this study and the importance of the expert ratings of the relatedness-judgment task.

Past research has shown that a referent pathfinder net predicts student's performance, even when the correlation between the expert's pathfinder nets is low (.31) (Acton, Johnson, & Goldsmith, 1994; Gonzalvo et al., 1994). For comparison in this investigation, following a common method, the four undergraduate university student's networks were all assembled to an average expert model.

Similarity of models. Based on prior structural knowledge research using pathfinder (Lim & Klein, 2006), we computed structural knowledge *similarity* by dividing the intersection by the union. Therefore, similarity between two pathfinder networks is obtained by averaging the number of links in common shared (e.g., the intersection of the two networks) divided by the total links (the union of the two networks) of the participant's network with the sequential and the expert referent networks. Links in common is the sum of the links shared by two networks (e.g., the intersection of the two networks). This network similarity measure ranges from 0 to 1, with values closer to 1 indicating greater similarity to the referent pathfinder net (see Lim & Klein, 2006). A second but more descriptive measure of network overlap is also provided, percent overlap. Percent overlap is defined as the intersection divided by the average total number of links. Both measures show the relationship between the participant's network and that of an expert.

Procedure

All tasks were completed in the Dutch language. Children were tested in their classes using the pretest MC questions. The experimental phase started two months later. The experiment was conducted in four lessons each considering one text passage (approximately 45min.) distributed over four days. Children were distributed at random in a within-subjects design over the four text types and four topics within these four lessons. Therefore, children read one of the four text passages in one of the four conditions in a randomized block design. For example, one child read about Oceania in LDT, Russia in DTO, South America in HT, and South Africa in HTO, whereas another child read about South America in DTO, Russia in HT, Oceania in HTO, and South Africa in LDT. It was controlled that all conditions appeared in the same amount. During the four reading sessions in the computer classroom, the children received written instructions, which were further clarified via oral explanation. They were instructed to read the text carefully and to answer the 20 multiple choice questions about the text during reading. There was no time limit. Children were familiar with the Internet and used the hyperlinks in the text as well as the overview to navigate between the pages. After reading a text and answering the MC questions, the children clicked on the KU-mapper icon on the desktop, opened the tool, and completed the relatedness-judgment task.

3

Data Analysis

To analyze children's situation models of the texts, the pathfinder KNOT software was used to convert the participants' relatedness-judgment raw proximity data into pathfinder nets. To generate the networks with the pathfinder scaling algorithm we applied standard parameters of $r = \infty$ and q = n-1 (Taricani & Clariana, 2006). Then the children's pathfinder nets were compared to an expert referent and the sequential referent.

A missing value analysis revealed 10.15% missing values. List-wise deletion would remove 55.91% of the cases. The little's MCAR test showed that the missing data were probably completely at random, $\chi^2 = 208.803$, $DF = 254$,

$p = .982$. We therefore adjusted the Expectation-Maximization (EM) algorithm to calculate the missing values (see Table in Appendix). To minimize the influence of any excessively high or low scores outliers based on the adjusted EM algorithm, extreme outliers (17.78%) were transformed to the mean plus two standard deviations.

Prior analyses of the data revealed that the scores of the sequential and expert similarity data in all four conditions were not normally distributed; therefore, a square root transformation on the similarity data was preformed which corrected for skewness and kurtosis of the data. The data revealed no high correlations (see Table 2; Field, 2005) and the multicollinearity statistic variance inflation factor (VIF) was within accepted limits, therefore, multi-collinearity was no matter of importance. Furthermore, children's prior knowledge of topics for each text type differed, because the text topics and text types (LDT, DTO, HT, HTO) were randomized, and children's comprehension performance on text topic 1 versus text topic 2, 3, and 4 depends also on each child's prior knowledge of the topic in each of the four text conditions. Hence, the prior knowledge scores were treated as another independent variable in the follow up regression analyses.

Results

Descriptive statistics and correlations for all scores (untransformed) are presented in Table 1. Regarding the first research question, how do children structure their situation models across different text types, a 4 Text Type (with/without links in the text and with/without overview) x 2 Similarity (sequential, expert) two-way repeated measures ANOVA analysis was performed. The results of the analysis revealed no significant main effect of Text type, $F(3, 267) = 1.244$, $p = .294$, $\eta^2_p = .014$. We found a main effect of Similarity, $F(1, 89) = 218.979$, $p < .001$, $\eta^2_p = .711$, indicating that children had overall more similarity with the sequential model than with the expert model. There was no significant interaction effect between Text Type and Similarity, $F(3, 267) = 2.158$, $p = .093$, $\eta^2_p = .024$.

Regarding the second research question, asking to what extent similarity with a linear and expert model predicts children's reading comprehension in these four digital text types, we conducted four hierarchical multiple regression analyses. In addition, we examined to what extent children's prior knowledge predicted reading comprehension in the four text types. The correlations are presented in Table 2. Similarity with the sequential model was entered at stage one. Similarity with the expert model variable was entered at stage two. In the final step, prior knowledge was entered to examine its effect above and beyond similarity with the models (Table 3).

Table 1 Mean Scores of Untransformed Similarity Data (Sequential & Expert), Reading Comprehension Scores (RC) and Prior Knowledge.

	% Similarity (SD)	% Overlap based on group average	Mean (SD)
Similarity sequential model LDT	19.03 (.07)	32.02	
Similarity sequential model DTO	17.66 (.27)	29.72	
Similarity sequential model HT	17.24 (.07)	29.00	
Similarity sequential model HTO	17.00 (.07)	28.60	
Similarity expert model LDT	13.68 (.06)	23.01	
Similarity expert model DTO	14.68 (.08)	24.70	
Similarity expert model HT	13.40 (.07)	22.54	
Similarity expert model HTO	13.46 (.07)	22.64	
RC LDT			12.80 (3.44)
RC DTO			12.41 (3.19)
RC HT			12.12 (3.86)
RC HTO			12.17 (3.80)
Prior knowledge			5.54 (2.00)

3

With reading comprehension in LDT as dependent variable, the results revealed that similarity with the sequential model predicted reading comprehension in LDT, $F(1, 87) = 6.773$, $p = .011$, $R^2 = .073$. Similarity with the expert did not add to this prediction, but prior knowledge explained additional variance in step 3, $F(1, 87) = 14.200$, $p \leq .001$, $R^2 = .213$. For reading comprehension in DTO, similarity with the sequential model again predicted reading comprehension, $F(1, 85) = 9.052$, $p = .003$, $R^2 = .096$. Neither similarity with the two models, nor prior knowledge added to this prediction. For reading comprehension in HT, again similarity with the sequential model predicted reading comprehension, $F(1, 86) = 8.564$, $p = .004$, $R^2 = .091$. But for this type of text, similarity with the expert model significantly added to this prediction, $F(1, 85) = 15.348$, $p \leq .001$, $R^2 = .230$, while prior knowledge did not add to this prediction. For reading comprehension in HTO as dependent variable, the same pattern was found as in HT. Similarity with the sequential model predicted reading comprehension in HTO, $F(1, 84) = 5.725$, $p = .019$, $R^2 = .064$, similarity with expert model added to this prediction, $F(1, 83) = 5.242$, $p = .025$, $R^2 = .119$, and prior knowledge did not. Similarity with the expert model was positively related to children's reading comprehension in HT and HTO when controlled for the predictive influence of similarity with the sequential model.

Table 2 Correlations of Reading Comprehension Scores, Transformed Similarity Data (Sequential & Expert), and Prior Knowledge.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Reading comprehension LDT	-												
2. Reading comprehension DTO	.447**	-											
3. Reading comprehension HT	.505**	.445**	-										
4. Reading comprehension HTO	.508**	.489**	.461**	-									
5. Similarity sequential model LDT	.273**	.208	.285**	.360**	-								
6. Similarity sequential model DTO	.227*	.303**	.203	.159	.383**	-							
7. Similarity sequential model HT	.304**	.311**	.302**	.276**	.112	.394**	-						
8. Similarity sequential model HTO	.210*	.234*	.262*	.248*	.294**	.262*	.358**	-					
9. Similarity expert model LDT	.229*	.149	.263*	.303**	.602**	.304**	-.002	.205	-				
10. Similarity expert model DTO	.136	.277**	.148	.191	.279**	.742**	.353**	.084	.180	-			
11. Similarity expert model HT	.395**	.411**	.469**	.412**	.277**	.362**	.751**	.370**	.165	.375**	-		
12. Similarity expert model HTO	.190	.364**	.357**	.345**	.293**	.419**	.380**	.696**	.137	.285**	.404**	-	
13. Prior knowledge	.371**	.107	.241*	.210	.012	-.003	.193	.319**	.046	-.066	.227*	.312**	-

** $p < .01$. * $p < .05$

Discussion

In order to gain more understanding of children's reading comprehension of digital text, we investigated the quality of children's knowledge structures of four digital texts that were diverse in form: linear digital text (LDT), digital text with overview (DTO), hypertext (HT), and hypertext with overview (HTO). Regarding the first research question, how children structure their knowledge representations across different digital text types, we examined the similarity of the children's knowledge structures with a sequential model as well as with an expert (hierarchical) model in the four digital text types. Interestingly, the results clearly show that children's knowledge structures in all digital text types had more similarity with the sequential model compared to the expert model, overall. We tentatively assume that the sequential model is guided by bottom-up processes and reflects text-based sequential knowledge structures (cf. Larkin & Simon, 1987), while the expert model reflects deeper comprehension in which more top-down processes of reading comprehension are involved. Children in our study thus seem to accomplish text-based sequential knowledge structures in all four digital text types. No interaction between model and text type was found. This finding is not completely in line with our expectation that children develop a sequential knowledge structure in reading a linear digital text and a more expert-like knowledge representation in reading digital text with hyperlinks or overviews. Children did not benefit from the overviews or hyperlinks, and did not seem to accomplish and expert-like situation model. It may be the case, that the simple hierarchical structures of the texts in the present study allowed a coherent sequential navigation. Furthermore, according to Amadieu, Tricot, and Mariné (2010), low-prior knowledge readers benefit from a hierarchical hypertext structure, which may help the reader to navigate coherently through the hypertext. Given that the complexity of the underlying structure of the digital text will likely have an impact on the structure of the situation model, more complex digital texts may induce more hierarchically structured situation models and thus may show larger differences.

Regarding the second research question, we examined to what extent similarity with a linear and expert model predicted children's reading comprehension in these different digital text types. In line with our expectations, we found that the sequential model predicted children's reading comprehension in all four digital text types. Interestingly, in addition to the bottom-up predictor of similarity with the sequential model, we found similarity with the expert model as a predictor of children's reading comprehension scores in hypertext (HT) and hypertext with overview (HTO), when controlled for similarity with the sequential model. Similarity with the expert network, which involves more

3

Table 3 Hierarchical Multiple Regression Analyses Predicting Reading Comprehension in Four Digital Text Types From Similarity with Sequential and Expert Model, and Prior Knowledge.

		Reading comprehension LDT				Reading comprehension DTO			
	Predictors	***B***	**SE *B***	***β***	***p***	***B***	**SE *B***	***β***	***p***
1	Constant	10.339	1.001		.001	10.084	0.851		.001
	Similarity sequential model	12.782	4.911	.270	.011	13.384	4.448	.310	.003
	R^2adj	.062				.086			
	ΔR^2	.073*				.096*			
2	Constant	10.046	1.063		.000	10.063	0.853		.001
	Similarity sequential model	9.682	6.189	.205	.121	9.191	6.644	.213	.170
	Similarity expert model	6.439	7.798	.108	.411	5.201	6.113	.131	.397
	R^2adj	.059				.083			
	ΔR^2	.007				.008			
3	Constant	6.665	1.336		.000	9.038	1.243		.001
	Similarity sequential model	10.178	5.759	.215	.081	8.671	6.649	.201	.196
	Similarity expert model	5.075	7.264	.085	.487	5.858	6.130	.148	.342
	Prior knowledge	0.626	0.166	.365	.001	0.185	0.163	.117	.261
	R^2adj	.185				.086			
	ΔR^2	.133**				.014			

** $p < .01$. *$p < .05$

top-down processes, is thus an additional predictor of children's hypertext reading comprehension. In line with this, children in the present study obtained sequential knowledge structures across all text formats of the present study but do not obtain a 'full' expert level understanding which we equate with a richer situation model, based on the construction-integration model. An explanation may be that the hyperlinks in hypertext may demand more inferences and can, to some extent, support children to form a more expert-like top-down situation model if appropriately designed. Active processing (inferences, planning, organizing) during reading is primarily advantageous at the situation model level (Eason et al., 2012; McNamara et al., 1996). After controlling for both, similarity with the sequential model and expert model, prior knowledge was a stronger predictor of children's reading comprehension scores only in linear

		Reading comprehension HT				Reading comprehension HTO			
	Predictors	*B*	SE *B*	*β*	*p*	*B*	SE *B*	*β*	*p*
1	Constant	9.073	1.112		.001	9.887	1.028		.001
	Similarity sequential model	17.689	6.044	.301	.004	13.324	5.569	.253	.019
	R^2adj	.080				.053			
	ΔR^2	.091*				.064*			
2	Constant	8.935	1.03		.001	9.588	1.011		.001
	Similarity sequential model	-7.108	8.448	-.121	.403	0.886	7.683	.017	.908
	Similarity expert model	33.105	8.45	.563	.001	17.831	7.788	.333	.025
	R^2adj	.212				.098			
	ΔR^2	.139*				.056*			
3	Constant	7.644	1.336		.001	8.718	1.312		.001
	Similarity sequential model	-7.584	8.392	-.129	.369	-0.771	7.843	-.015	.922
	Similarity expert model	31.542	8.453	.537	.001	17.098	7.816	.320	.032
	Prior knowledge	0.284	0.189	.146	.137	0.224	0.215	.115	.302
	R^2adj	.223				.099			
	ΔR^2	.020				.011			

digital text (LDT). Overviews and hyperlinks thus seem to diminish the effects of prior knowledge and hence support the comprehension process for children who are often by definition low-prior knowledge readers.

Implications for Design and Instruction

One limitation of the present study is that we did not examine the enduring advantages in different knowledge structures in a delayed retention test. Given that there is a great deal of individual variation in child characteristics in elementary schools, the present study does not account for individual differences and the role of cognitive and linguistic child characteristics for the quality of knowledge structures. Furthermore, the navigation path and number of hyperlinks in the digital texts used in the present study were constrained, because the texts were presented in a closed digital text environment. Implication of this study should be regarded with caution, as more complex digital texts may very well lead to disorientation and cognitive overload in children. The present study does not examine children's amount of disorientation, however, the structure of children's knowledge representation can give implications for disorientation (Otter & Johnson, 2000). Finally, the present study examined hypertext instead of hypermedia to exclude any modality effect. Follow-up research is needed to gain further insights in children's hypermedia reading comprehension.

Future Research

In future studies, the quality of children's knowledge structures may be used in longitudinal studies to examine the structure of the situation model of digital text in combination with learning to shed light on the interplay of bottom-up and top-down processes and the role of cognitive and linguistic child characteristics. Longitudinal measures of readers' knowledge structures could reveal a gradual transition from predominately sequential to more-and-more like an expert's knowledge structure. Furthermore, to examine the effect of memory on the quality of children's knowledge structures in different digital texts, it would be interesting to answer the comprehension questions and to run the relatedness-judgment task after reading the text. Also, quality of children's knowledge structures may be used in intervention studies to examine how digital text comprehension should be taught given the fact that the reading curriculum in elementary schools does not focus on digital texts, yet. Finally, the effect of strategy training and self-regulated skills on the quality of children's knowledge structures in digital text may be examined.

Conclusion

The most important conclusion of the present study is that children basically followed a sequential approach in forming knowledge structures across all digital texts. Our finding that children's knowledge structures in each of the four text conditions were more in line with the sequential model than with the expert model strongly indicates that a sequential strategy was used both in linear digital text and in hypertext reading. Interestingly, however, we also found an indication that reading hypertext may foster deeper understanding given that hypertext comprehension was also predicted by similarity with an expert model.

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Appendix

Table A1 Imputations of Raw Data and Comparison Between the Original Data and the Calculated Data.

	Raw dataset					Imputation				
Variable	**N**	**Min**	**Max**	**Mean**	**SD**	**N**	**Min**	**Max**	**Mean**	**SD**
Similarity with sequential model										
LDT	78	.02	.44	.1581	.08008	93	.02	.44	.1605	.07565
DTO	79	.03	.41	.1467	.07791	93	.03	.41	.1457	.07255
HT	70	.01	.37	.1412	.06740	93	.01	.37	.1422	.06124
HTO	76	.02	.37	.1349	.07213	93	.02	.37	.1354	.06774
Similarity with expert model										
LDT	78	.00	.30	.0923	.06030	93	.00	.30	.0930	.05667
DTO	80	.00	.39	.0919	.06959	93	.00	.39	.0924	.06581
HT	71	.00	.27	.0861	.05898	93	-.01	.27	.0858	.05587
HTO	75	.00	.28	.0964	.06095	93	.00	.28	.0972	.05852
Valid N listwise	41									

Chapter 4

How hypertext fosters children's KNOWLEDGE ACQUISITION: The roles of text structure and graphical overview

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Abstract

Children in primary and secondary school are asked to go on the Internet for school purposes while research on hypertext has scarcely investigated how children process and learn from hypertext. We therefore examined how hypertext influences children's knowledge acquisition from expository text. A group of 71 Dutch children (13 years old) from one secondary school for pre-university education participated in the study. In a within-subjects design with four conditions, we compared: linear digital text, digital text with overview, hypertext, and hypertext with overview. Children's (a) navigation (i.e., reading time and navigation pattern) and (b) learning (i.e., multiple choice knowledge questions and mind maps) was measured. Although reading times did not differ, the children navigated less linearly in both hypertext conditions than in the digital text with overview condition. The four types of text led to the same deep understanding as measured on the text-base level. Analyses of the mind maps, however, showed the children to construct richer situation models after reading hypertext or hypertext with an overview relative to linear digital text and digital text with overview. We therefore conclude that hypertext fosters a deeper level of information processing when appropriately designed relative to linear digital text.

Introduction

Rapid developments in the field of computers and the Internet are increasingly influencing contemporary education. A huge amount of information is easily accessible via the Internet, which means that readers are being confronted with more and more hypermedia documents and hypertext (Fesakis, Sofroniou, & Mavroudi, 2011). Given that the structure and content of a hypertext system are not specified and unpredictable, there is a greater degree of reader control, because the reader has to determine his/her own pathway, which places additional demands on the cognitive resources and executive function. Executive function encompasses cognitive flexibility; students must shift their behavior and cognition to the changing demands of hypertext to form concepts. Hypertext studies have indeed shown that high levels of prior domain knowledge and process knowledge enhance focused behavior as goal directed navigation which may facilitate learning from hypertext (Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009; see also Amadieu, Tricot, & Mariné, 2009). During the reading process they must select and decide about the reading order of the links in a hypertext document to establish a coherent reading path, based on the reader's experience, interest, prior knowledge, comprehension and reading goals (Landow, 1992; Salmerón, Kintsch, & Cañas, 2006; Waniek, 2012). To date, research on the reading of hypertext has mostly focused on adults (DeStefano & LeFevre, 2007). Studies regarding children and the Internet have focused on their information search strategies and not their learning (see for review, Kuiper, Volman, & Terwel, 2005). In the present study, we therefore investigated children's comprehension of reading linear digital text versus hypertext, either with or without the support of a graphic overview.

Models of Hypertext Learning

Two models of learning from traditional linear text have shaped research on hypertext processing and are mainly based upon theories of reading and learning (Shapiro & Niederhauser, 2004). In the Construction-Integration Model (Kintsch, 1988), it is assumed that the reader must relate representations of the ideas from a text and hypertext at three static stages in order to comprehend the text and actually learn from it. First of all, the reader has to *decode* the words in the text. Second, the reader must build a *text base* from a text. Comprehension is very superficial at this stage and based on pure details and facts from the text. To build coherent representations, the text base must be integrated with the reader's prior knowledge to form a so-called *situation* or mental model. It is generally assumed that active learning is necessary to form a situation model

(Juvina & Van Oostendorp, 2008; Kintsch, 1994; Shapiro & Niederhauser, 2004).

The second model of learning from traditional linear text is based on the Cognitive Flexibility Theory (Shapiro & Niederhauser, 2004; Spiro, Coulson, Feltovitch, & Anderson, 1988), which postulates for reading hypertext, that the reader must flexibly integrate prior knowledge with multiple knowledge structures from ill-structured hypertext document into existing knowledge and reorganize the existing knowledge structures in order to build a situation model (Spiro, 1991). When new information does not fit into existing schema, it is assumed that the reader must readjust and restructure the existing schema or create new schema to accomplish flexible and transferable knowledge (Shapiro & Niederhauser, 2004; Smith-Gratto, 2000).

Both models describe prior knowledge as a key factor for the creation of a situation model and attainment of a sufficiently deep understanding of new material. According to the Construction Integration Model, low-prior knowledge readers may have to go through a static comprehension process to develop a situation model (Shapiro & Niederhauser, 2004). However, in Cognitive Flexibility Theory, it is assumed that mental representations are constructed and combined in order for deep and flexible learning to occur. According to the Cognitive Flexibility Theory, children have to reconstruct and alter their situation model for deep learning. In line with these two current models of learning from hypertext, active reading engagement is viewed as a necessary condition for such meaningful learning (Kintsch, 1998; Shapiro & Niederhauser, 2004).

Both, semantic and structural knowledge is relevant for navigation on the Internet (Juvina & Van Oostendorp, 2008). For readers with low-prior knowledge, reading comprehension scores and free recall performance have been found to be higher after reading a hierarchically organized hypertext as opposed to a networked hypertext, because the former provides a more coherent navigation path than the latter (Amadieu et al., 2009; Calisir, Eryazici, & Lehto, 2008). Finally, hypertext reading time has been found to positively correlate with hypertext learning in adults (Niederhauser, Reynolds, Salmen, & Skolmoski, 2000). The reader must monitor his/her comprehension and cope with the hypertext demands. However, many readers of hypertext fail to regulate their learning (Azevedo & Cromley, 2004).

Drawing mind maps may help in this case. There is a great deal of evidence that drawing mind maps enhances deep processing of the information and may enhance learning (Nesbit & Adesope, 2006). Adolescents or undergraduate students create a mental model or knowledge representation of the hypertext in the form of a schema (Otter & Johnson, 2000; Waniek, 2012). The interest in measuring readers mental models grows and one method to measure the mental model of a reader are mind maps or knowledge maps (O'Donnell, Dansereau, & Hall, 2002). A mind map represents ideas as node-link associations and is an organizational strategy for comprehending text. Specifically, mind maps have no conventional linear reading order and may be therefore especially suited in reconstruction the situation model of a hypertext. This method of measuring learning is relevant to hypertext learning. This method of measuring learning is relevant to hypertext learning; regarding the Cognitive Flexibility Theory a reader may access a hypertext from multiple perspectives resulting in flexible mental models, which should be reflected in the mind map of the reader. However, children are low-prior knowledge readers and may have to go through the static comprehension process described in the Construction-Integration Model for knowledge construction to develop a situation model and comprehend a hypertext. Particularly with regard to the Cognitive Flexibility Theory, children have to reconstruct and alter their situation model flexible as demanded by the hypertext design and integrate their prior knowledge with new information for deep processing and meaningful learning. Therefore, children may construct different mental models as well as mind maps from hypertext compared to linear text.

Role of Graphical Overviews

Graphical overviews are often provided in hypertext in order to invoke prior knowledge and facilitate the construction of a situation model. The presence of graphic overviews can facilitate learning (Salmerón et al., 2009). They may help the reader to avoid disorientation and overly high cognitive demands (for review, see DeStefano & LeFevre, 2007; Wright, 1991). The organization of the main ideas in a text certainly guides navigation through the text and the construction of a situation model (Madrid, Van Oostendorp, & Melguizo, 2009; Salmerón et al., 2006). According to schema theory (Anderson & Pearson, 1984), words presented in an overview can serve as cues for comprehension and support the building of relations between concepts. And in several studies, graphical overviews in hypertext documents have indeed been shown to foster the building of a macrostructure for the text and a coherent reading order (Amadieu et al., 2009; Müller-Kalthoff & Möller, 2005; Naumann, Richter, Flender, Christmann, & Groeben, 2007; Potelle & Rouet, 2003; Salmerón et al., 2006; Vörös, Rouet, & Pléh, 2011).

Graphical overviews can be static or dynamic with hyperlinks in the overview and arranged alphabetically or hierarchically. A graphical overview with a matching spatial layout is better recalled than an alphabetically structured graphical overview because it facilitates spatial mapping process (e.g., an index; Dee-Lucas & Larkin, 1995; Vörös, Rouet, & Pléh, 2011). Research has shown hierarchically structured overviews to lead to better learning performance than unstructured, networked, or alphabetically structured overviews (Amadieu et al., 2009). And while hierarchical overviews in hypertext have been found to foster the same level of understanding as list overviews for undergraduate students with either high or low-prior knowledge (Hofman & Van Oostendorp, 1999; Salmerón et al., 2009), hierarchical overviews read at the beginning promoted better comprehension of hypertext than list overviews, particularly in sixth-graders with low-prior knowledge (Naumann et al., 2007; Salmerón & García, 2011).

A Developmental Perspective

Most research has focused on the hypertext reading comprehension strategies of skilled readers who are proficient readers of linear text, mainly adolescents or undergraduate students. The degree to which those findings hold for children with far less reading experience is thus unclear. Due to less content knowledge but also process knowledge, it can be assumed that the hypertext reading strategies of children will differ from those of adults (Salmerón & García, 2011). Puntambekar and Goldstein (2007) examined the effects of navigable overview versus a list of concepts on adolescent's comprehension and they found the form of the overview (i.e., concept map vs. outline) does not make a difference for the learning of pure facts but readers in the navigable overview condition nevertheless showed deeper and richer text comprehension. When Kerr and Symons (2006) examined the effects of linear text presented in printed form versus reading from a computer monitor on children's (grade five) reading times, comprehension, and recall, they found the children to read faster from paper. However, no evidence was found for differences in the reading strategies of the children in the two conditions (Kerr & Symons, 2006).

When Salmerón and García (2011) examined the hypermedia reading comprehension of sixth graders (11 years old) from a Spanish public primary school, they found the skilled readers to be able to use a cohesive hyper-linking strategy, which positively correlated with hypertext reading comprehension in turn. Skilled readers were also found to use an initial overview processing strategy (Salmerón & García, 2011).

The Present Study

Previous studies have examined children's navigation and link selection strategies in hypertext but not the influence of different (hyper)text structures on the children's learning (i.e., knowledge acquisition and building of a situation model), navigation patterns or reading times. In the present study, we investigated how 13-year-old Dutch children learn from text in four experimental conditions:

text structure (linear digital text versus hypertext) and presence or absence of graphical overview. The children's learning outcomes and situation models were compared across conditions in addition to their reading times and navigation patterns in order to answer the following questions.

Q1: How do text structure and the presence of graphical overviews influence children's text comprehension and construction of situation models?
Q2: How do text structure and the presence of graphical overviews influence children's reading times and patterns of navigation through a text?
Q3: How do children's patterns of navigation in both hypertext conditions relate to their construction of situation models?

Method

Participants

Seventy-one children (36 girls, 35 boys, M_{age} = 13.1 years, age range: 11 – 13 years) from three seventh grade classes from a single Dutch secondary school for pre-university education participated in the experiment. Two other participants were excluded because of dyslexia and very low scores on a technical reading skills test. Some children had incomplete data, resulting missing data at random. The participants had normal or corrected-to-normal vision and none reported any difficulties in reading the texts from the computer screens. The children were unfamiliar with the purpose of the experiment. All parents or primary caregivers provided written consent.

Text Materials

All children read four text conditions: linear digital text (LDT), digital text with an overview (DTO), hypertext (HT), and hypertext with an overview (HTO) (see Appendix A and Figures A1 – A4). The LDT condition contained linear digital text with four headings, six subheadings, and page numbers. The children could navigate between the pages of the text by clicking on forward and backward buttons. The DTO condition contained the linear digital text supplemented with a navigable overview with a hierarchical structure at the top of each page. The overview consisted of the ten headings from the linear text (i.e., four chapter headings and six subchapter headings). The children could navigate between the pages in this condition by clicking on one of the ten hyperlinks in the overview. The HT condition contained the linear digital text plus ten hyperlinks within the text that were identical to the keywords in the text headings. The links were standard blue and underlined; when activated by clicking on them, they changed from blue to gray. A "home" button on the final page also enabled the reader to go back to the first page in this condition. The HTO condition contained the hypertext supplemented by the same hierarchical overview as in the other overview condition. Just as in the other overview condition, the words in this overview were links; this meant that this condition contained a total of 20 links.

According to the within-subjects design, all participants read all four text conditions; however, to exclude an effect of text topic, the four text conditions were designed in four different text topics, resulting in 16 text materials (4 text types × 4 topics). The text materials were four expository geography texts from textbooks written for this age (The Reader's Digest, 2002): Oceania, Russia, South America, and South Africa. The text conditions LDT, DTO, HT and HTO as well as the four text topics were counterbalanced and presented in a random order to reduce the possibility of order effects. Hence, each child read four different text types with four different topics; for example one child read in the LDT condition about Oceania, in the DTO condition about Russia, in the HT condition about South-America and in the HTO condition about South-Africa. Another child read in the LDT condition about Russia, in the DTO condition about South-America, in the HT condition about South Africa and in the HTO condition about Oceania. The texts had a hierarchical structure, which was distributed across 10 pages and an average of 974 words ($SD = 36.21$). The topic was introduced on the first page and then followed by three main chapters and two subchapters per main chapter.

Microsoft Internet Explorer 8 for Windows® XP was used to present the text materials. Children read the texts in full screen mode to prevent them from searching for other things on the Web. And while the children read the texts in the four conditions, their navigation operations were recorded using the freeware CamStudio™ screen recorder and their reading times were registered in log-files.

Learning Measures

Knowledge tests. To assess the children's knowledge after reading a particular text, 20 multiple choice (MC) questions with four possible answers were constructed for each of the four texts. Ten of the MC questions referred to explicit knowledge and ten referred to implicit knowledge. The explicit questions were factual or related verbatim to the text (example of an explicit question: "The Kagu in Oceania belongs to which species group? (a) Mammals, (b) Birds, (c) Reptiles, (d) Insects"); the implicit questions required the children to make inferences and draw conclusions (example of an implicit question: "Why is a tree in Oceania called breadfruit tree? (a) Because the fruits are the same for the people in Oceania as fresh bread is for us, (b) Because the fruit tastes similar to bread, (c) Because the fruits look like cinnamon buns (d) Because many birds brood in the trees). A Web-based application (PERSEUS) was used to administer the MC questions. In a pilot study, 67 sixth-grade children from five different Dutch schools read the four texts in a paper version of the LDT condition and answered the MC questions for the four texts. The pilot results showed a sufficient alpha for the explicit MC questions (α = .84) and implicit MC questions (α = .73). Based on the pilot results, conspicuous features in text passages and MC questions were revised. For the prior knowledge test, four questions (two implicit and two explicit questions per topic) were randomly chosen out of twenty MC questions for each of the four texts. These sixteen MC questions were used to assess the children's amount of prior knowledge.

Mind maps. To assess the situation models constructed by the children, they were asked to draw a mind map following the reading of each text. To ensure that the children were familiar with the concept of mind mapping and to reduce differences in experiences the children received one lesson (40 min) in mind mapping by the first author. During this lesson the children learned by means of examples of good and bad mind maps that a mind map arranges links and concepts around a central key word and is known to help readers organize and visualize new information (Davies, 2011). For an open mind map, the creator chooses the relevant concepts him/herself and arranges them on the basis of his or her knowledge. Figure 1 shows a mind map from a child who participated in this experiment. The content of all the mind maps was checked for concepts and/or associations outside the scope of the four texts to control for content. Two raters counted the *number of concepts* (words) as well as the *number of hierarchies*. A hierarchy was the combination of at least a *first* and *second level concept link*. Concepts placed next to the central key represented first level links. Concepts then linked to the first level links represented second level links. Concepts linked to the second level links represented third level links. The extremities or last concepts of a hierarchy were counted to determine the total number of hierarchies. The scoring of the mind maps was based on the scoring system of Evrekli, Ïnel, and Balim (2010). First level links were assigned two points, second level with four points, and third level links six points. The total number of points for the mind maps thus indicated their *complexity*.

For the present study we employed one undergraduate student of Educational Science to rate the number of concepts, of hierarchies and complexity of the mind maps. The student was previously familiar with mind maps and the idea that concepts that were arranged around a central key word help readers to organize and visualize information. In addition, the lesson for the children was shown to the student for a deeper insight. The undergraduate pedagogic student was inexperienced in coding, but received one hour of training in scoring mind maps. The first author did the second rating. Because of the standardized scoring method, the raters had no disagreement during the training session.

Figure 1 An example of a mind map from a child, drawn in the hypertext condition of this study.

To measure the inter-rater reliability of the mind map scoring system we calculated *kappa k* for the first and second level of the mind maps. For the first level of the mind maps, a kappa of k = .95 was calculated, indicating almost perfect agreement between the two raters (of which one was the first author of this paper). For level 2 kappa was k = .84, indicating excellent agreement between the two raters (Cohen, 1960).

Navigation Measures

Reading time. For each text, the reading time was recorded when the child logged onto the first page and ended when the child clicked on the button "finished reading".

Navigation pattern. The length of the reading path was determined from the log-files and consisted of the number of pages clicked on by the children to be read. Based on the hierarchical structure of the texts, the degree of linearity was also determined (Amadieu, Tricot, & Mariné, 2010). To begin with, a coherence score was computed. A score of 1 point was assigned when a jump was made to a text section that was deeper in the hierarchy and/or a jump between two text sections belonging to the same category within the same level of the hierarchy. To calculate the linearity score, the coherence score was divided by the total number of pages read. A linearity score of 1 indicates a maximally linear reading pattern. The number of pages read and the linearity scores were also calculated for the first 10 pages read as this reading is known to be crucial for identification of the macrostructure of a text or the "meaningful whole" (Kintsch & Van Dijk, 1978).

Child Characteristics

Two child characteristics were measured as control variables. First, the children's technical reading skills were assessed with a Dutch silent Lexical Decoding Test consisting of 120 disyllable words (van Bon, 2007). Some of the words are nonsense or non-existing words. During the test, the participant has to cross out as many nonsense words as possible during the time limit of one minute. Second, the children's computer literacy was measured with a computer and Internet experience questionnaire with seven items ranging from a 2 point scale up to a 5 point scale (Citogroup, http://toetswijzer.kennisnet.nl).

Procedure

The experiment was conducted as a within-subjects design during five lessons of 45 minutes each, distributed across five days. The experimental sessions were run in the computer room of the school with three groups of up to 27 children that were measured at once with the same materials and procedure. At pretest on the first day, the children answered sixteen MC questions to assess the amount of prior knowledge. Their reading skills and computer literacy were also assessed.

In the experimental phase, the children received written instructions, which were further clarified via oral explanation by the researcher. They were instructed to read each text carefully and without a time limit so that they would be able to answer 20 MC questions about the text afterwards. The children read one of the four text versions at random in one session. They had to click on a "finished reading" button on the last page of the LDT version and on the introduction page of the DTO, HT and HTO versions. This procedure was used to determine the overall reading duration (in ms); it also prevented the children from searching in the text to answer the MC questions. After reading a text, the children answered the MC questions and drew a mind map about the text they had read. The four sessions were held across a period two weeks.

Results

Analyses of Learning Outcomes

The pretest scores for the children's prior knowledge as measured using a subset of the MC questions (16 questions; $M_{correct} = 5.72$, $SD = 1.94$) confirmed that they had little or no prior knowledge of the four geography topics. Furthermore, the children had good technical reading skills ($M = 103.03$, $SD = 14.28$) and had a lot of experience working with a computer and the Internet ($M = 23.67$, $SD = 1.56$). Table 1 shows the learning outcomes for the four text conditions.

Table 1 Means and Standard Deviations for Learning Outcomes: Knowledge Test and Mind Maps Following The Reading of Linear Digital Text (LDT), Digital Text With an Overview (DTO), Hypertext (HT), or Hypertext With an Overview (HTO).

Measure	**LDT** *M (SD)*	**DTO** *M (SD)*	**HT** *M (SD)*	**HTO** *M (SD)*
Knowledge test				
Explicit MC questions	6.38 (2.09)	6.62 (1.78)	6.02 (2.18)	6.18 (2.13)
Implicit MC questions	5.29 (1.89)	5.68 (1.88)	5.19 (2.05)	5.58 (2.02)
Mind maps				
N concepts	14.18 (7.40)	14.47 (7.06)	14.93 (7.67)	14.76 (6.33)
N hierarchies	7.40 (5.01)	7.92 (4.15)	7.72 (4.88)	8.25 (3.87)
N concept links				
First level	4.17 (2.09)	3.41 (1.69)	3.66 (1.31)	3.51 (1.78)
Second level	5.91 (3.39)	5.87 (2.63)	5.74 (3.27)	6.22 (2.25)
Third level	3.23 (3.87)	4.02 (3.86)	4.14 (3.74)	4.90 (3.98)
Complexity	50.84 (30.40)	54.26 (26.89)	56.74 (31.64)	60.17 (26.76)

Knowledge test. A repeated measures ANOVA with Text Type (LDT, DTO, HT, HTO) and Question Type (explicit, implicit) as between-subjects variables revealed a main effect of Text Type, ($F(3, 162) = 2.99$, $p = .033$, $\eta^2_p = .05$). Pairwise comparisons using Bonferroni correction indicated higher knowledge scores in the DTO condition than in the HT condition ($p = .023$). The LDT, HT, and HTO conditions did not differ significantly from each other (all ps > .05). There was also a main effect of Question Type: The children answered more explicit questions correctly than implicit questions, ($F(1, 54) = 29.83$, $p \leq .001$, $\eta^2_p = .36$). There was no interaction between Text Type and Question Type ($F < 1$).

Mind maps. The mind maps were analyzed in a series of repeated measures ANOVAs with Text Type as the within-subjects variable and the following dependent variables: number of concepts; number of hierarchies; number of first, second, and third order concept links; and complexity. Main effects were further analyzed using post hoc pairwise comparisons with Bonferroni correction (see Table 2 for an overview).

Table 2 Overview of Significant Findings for Number of Concepts, Number of Hierarchies, Number of First/Second/Third Order Links, and Complexity of the Mind Maps Across Text Types.

Mind maps			
N concepts	HTO	>	DTO
N hierarchies	HTO	>	DTO
N concept links			
Level 1	No differences		
Level 2	No differences		
Level 3	HTO	>	LDT
	HTO	>	DTO
Complexity	HTO	>	LDT
	HTO	>	DTO
	HT	>	DTO
	HTO	=	HT

Number of concepts. There was a main effect of Text Type, ($F(3, 108) = 3.47$, $p = .019$, $\eta^2_p = .09$). Further analyses showed this effect to be due to the children using slightly more concepts in the HTO condition than in the DTO condition ($p = .059$).

Number of hierarchies. The text types differed statistically with regard to the number of hierarchies found in the mind maps constructed by the children following their reading, ($F(3, 99) = 2.72$, $p = .048$, $\eta^2_p = .08$). The children constructed significantly more hierarchies in the HTO condition than in the DTO condition ($p = .031$). No significant differences were found between the other text conditions.
Number of first, second, and third level links. The data of the first, second, and third level links were non-normally distributed and analyzed with a nonparametric ANOVA (Friedman's). The number of first and second level links did not differ significantly between the four for text conditions (all *ps* $> .05$). However, the third level links differed statistically depending on Text Type, ($\chi^2(3) = 24.89$, $p \leq .001$). Post hoc analyses with Wilcoxon tests showed that, the mind maps drawn in the HTO condition had more third level links than those drawn in both the LDT condition ($z = -2.53$, $p = .011$), and DTO condition ($z = -2.92$, $p = .004$). In the HT condition the mind maps had more third level links than the mind maps in the LT condition ($z = -2.75$, $p = .006$).
Complexity. Also for the complexity of the mind maps, a significant main effect of Text Type was found, ($F(3, 102) = 7.35$, $p \leq .001$, $\eta^2_p = .18$). The children produced more complex mind maps in the HTO condition relative to both the LDT condition ($p = .002$) and the DTO condition ($p \leq .001$) but not relative to the HT condition. The HT condition also differed from the DTO condition ($p = .048$) with more complex mind maps in the former than in the latter.

Analyses of Navigation Outcomes

Table 3 shows the outcomes for the process measures for the four text conditions.

Reading time. A Friedman's ANOVA with Text Type (LDT, DTO, HT, HTO) as the within-subjects variable was conducted on Reading Time (see Table 3). Children spent the same amount of time reading the four text documents ($p = .210$).

Length of reading path. A Friedman's ANOVA for the total length of the reading path indicated significant differences for Text Type, ($\chi^2(3) = 49.19$, $p \leq .001$). The children revisited significantly more pages in the HT condition and had accordingly longer reading paths than in all of the other conditions (all *ps* $< .05$). They also revisited more pages in the HTO condition than in the DTO condition ($p = .001$).

Linearity of navigation pattern. The children have – by definition – to read linearly in the LDT condition; all of the linearity scores in this condition were therefore 1 (see Table 3). Hence, the linearity scores in the LDT condition were non-normally distributed. To examine whether the *number of links* in the text

Table 3 Means and Standard Deviations for Navigation Outcomes: Reading Time, Navigation Pattern, and First Ten Navigation Clicks According to Text Condition.

Measure	**LDT M (SD)**	**DTO M (SD)**	**HT M (SD)**	**HTO M (SD)**
Reading time (ms)	645.02 (175.82)	599.70 (185.75)	593.01 (187.54)	652.60 (180.79)
Navigation pattern				
Length of reading path	14.27 (7.76)	11.56 (3.14)	22.24 (5.80)	15.32 (7.33)
Linearity of navigation pattern	1.00 (0.00)	0.81 (0.11)	0.90 (0.07)	0.78 (0.15)
First ten navigation clicks				
Linearity of navigation pattern	1.00 (0.00)	0.89 (0.14)	0.95 (0.06)	0.89 (0.14)
Total number of different pages	9.37 (1.23)	9.36 (0.91)	5.74 (0.80)	8.85 (1.36)

conditions influenced the *linearity of the navigation pattern* or not, a Friedman's ANOVA on the navigation data was conducted with text condition (LDT, DTO, HT, HTO) as a within-subjects variable. The linearity of the children's navigation patterns differed significantly across the four text conditions, ($\chi^2(3) = 86.50$, $p \leq .001$). Post hoc analyses with Wilcoxon tests showed all of the text conditions to differ significantly from each other. The linearity of reading was significantly higher in the LDT condition than in: the HT condition ($z = -5.44$, $p \leq .001$), the DTO condition ($z = -5.91$, $p \leq .001$), and the HTO condition ($z = -5.78$, $p \leq .001$). HT was also read more linearly than both DTO ($z = -3.75$, $p \leq .001$) and HTO ($z = -4.53$, $p \leq .001$). The children's reading in the DTO condition was also significantly more linear than their reading in the HTO condition ($z = -2.13$, $p = .033$).

4

First ten navigation clicks. Regarding the children's *first ten navigation clicks* (see Table 3), the Friedman's ANOVA revealed significant differences between the first ten clicks in all four of the text conditions, ($\chi^2(3) = 36.71$, $p \leq .001$). Post hoc analyses using Wilcoxon tests showed significantly more linearity for the first ten navigation clicks in the LDT condition compared to: the HT condition ($z = -4.43$, $p \leq .001$), the DTO condition ($z = -4.58$, $p \leq .001$), and the HTO condition ($z = -4.29$, $p \leq .001$). HT was also read significantly more linearly compared to both DTO ($z = -2.82$, $p = .005$) and HTO ($z = -2.16$, $p = .031$). The linearity of the first ten navigation clicks did not differ significantly for the HTO condition versus the DTO condition, however ($z = -0.35$, $p = .725$).

We also examined the number of different pages read on the first ten navigation clicks. A repeated measures ANOVA revealed significant differences between the text conditions, ($F(3, 147) = 123.62$, $p \leq .001$, $\eta^2_p = .72$). Post hoc comparisons showed the number of different pages read by the children during the first ten navigation clicks to be lower in the HT condition than in all of the other conditions: LDT, DTO, and HTO (all ps $\leq .001$). The LDT, DTO, and HTO conditions did not differ statistically from each other (ps $< .05$). In the HT condition, the children apparently decided to go back to difficult or unclear text passages rather than to new passages, thus, they switched more often between the same pages resulting in higher linearity scores than in the other text conditions. In the other text conditions (i.e., LDT, DTO, and HTO), the children read almost all ten pages during the first ten navigation clicks. This means that the children build better macrostructures in not only the DTO and HTO conditions but also the LDT condition compared to the HT condition.

Relations between navigation outcomes and learning outcomes. The linear and quadratic relations between the length of the reading paths and the outcome variables for only the HT and HTO conditions were calculated and are summarized in Table 4. The linearity scores in the LDT condition were all 1 and could therefore not be analyzed here. The DTO condition was also disregarded here because there were no hyperlinks in this text condition that could influence navigation during reading. The comparison of the HT and HTO conditions showed mostly non-significant relations between the length of the reading path and the children's total knowledge scores following the reading of the texts (all ps $> .05$). The one exception to this was the HTO condition where a linear relation was found ($R^2 = .285$, $p \leq .001$): Those children who visited more pages in this condition also answered more of the MC knowledge questions correctly.

With regard to the number of concepts in the children's mind maps, no significant relationships were found (all ps $> .05$). Similarly, in the HT condition, there were no significant relations between the length of the reading paths and the number of hierarchies in the children's mind maps. However, in the HTO condition, a quadratic relation was found ($R^2 = .237$, $p = .006$). When the number of visited pages increased to an optimum, the number of hierarchies in the mind maps also increased; further increases in the number of pages visited, however, was associated with mind maps with less hierarchies.

When the possible relations between the length of the reading path and the number of first-level concept links occurring in the children's mind maps were analyzed, once again: no significant associations were found in the HT condition. However, a quadratic relation was found in the HTO condition ($R^2 = .213$, $p = .004$), such that when the number of visited pages increased to an optimum, the number

Table 4 Linear and Quadratic Relation Results for Length of Reading Path and Outcome Variables in Two Hypertext Conditions.

Measure	**HT**	**HTO**
Knowledge test		
Total scores (sum of explicit and implicit questions)	Linear: $R^2 = .004$ ($p = .676$) Quadratic: $R^2 = .017$ ($p = .489$)	Linear: $R^2 = .285$ ($p = .000$) Quadratic: $R^2 = .321$ ($p = .155$)
Mind maps		
N of concepts	Linear: $R^2 = .074$ ($p = .110$) Quadratic: $R^2 = .079$ ($p = .658$)	Linear: $R^2 = .062$ ($p = .132$) Quadratic: $R^2 = .081$ ($p = .402$)
N of hierarchies	Linear: $R^2 = .008$ ($p = .612$) Quadratic: $R^2 = .009$ ($p = .844$)	Linear: $R^2 = .045$ ($p = .207$) Quadratic: $R^2 = .237$ ($p = .006$)
N of concept links Level 1	Linear: $R^2 = .002$ ($p = .806$) Quadratic: $R^2 = .003$ ($p = .832$)	Linear: $R^2 = .000$ ($p = .963$) Quadratic: $R^2 = .213$ ($p = .004$)
Complexity	Linear: $R^2 = .006$ ($p = .647$) Quadratic: $R^2 = .009$ ($p = .779$)	Linear: $R^2 = .002$ ($p = .794$) Quadratic: $R^2 = .194$ ($p = .007$)

4

of first-level concepts of the mind maps also increased; further increases in the number of pages visited, however, was associated with an increasing number of first-level concepts.

Furthermore, a quadratic relation was found between the length of the reading path in the HTO condition and the complexity of the children's mind maps in this condition ($R^2 = .194$, $p = .007$): When the number of visited pages increased to an optimum, the complexity of the mind maps also increased; further increases in the number of pages visited, however, was associated with mind maps of a reduced quality.

In sum, the significant quadratic relationships that we found showed the number of hierarchies, the number of first level concept links, and the complexity of the children's mind maps to generally increase as the number of pages visited by the children in the HTO condition increased; further increases in the number of pages visited, however, were associated with decreased scores and thus a lower quality of mind map in the HTO condition.

Discussion

In the present study we examined children's hypertext learning and reading behavior and the added value of graphical overviews. The first research question focused on learning outcomes, as measured by a knowledge test and the analysis of the mind maps created by the children following the reading of a text/hypertext. The *knowledge test* results, which reflected the children's learning on the text-base level, showed the children to learn more in the digital text with overview condition as opposed to the hypertext condition. The children learned just as much in the hypertext and hypertext with overview conditions as in the linear digital text condition on the text-base level. The seventh-grade children answered more of the explicit knowledge questions correctly than the implicit knowledge questions. These results show the seventh-grade children in our study to have problems drawing inferences with regard to new topics after having read a medium sized text. The knowledge test results occurred independent of text type and the presence/absence of a graphical overview.

With regard to the children's *mind maps*, the results show the children to produce more complex and detailed mind maps in the hypertext and hypertext with overview conditions than in the linear digital text and digital text with overview conditions; research by Puntambekar and Goldstein (2007) supports this finding. It can thus be tentatively concluded that hypertext and hypertext with overview elicits a more active mode of information processing. These results are in line with the generally positive findings found for hypertext comprehension (Dee-Lucas & Larkin, 1995). The complex mind maps of the children in the hypertext with overview condition may also be due to the fact that not only the links in the text but also the nonlinear structure of the hypertext prompted the children to adopt and focus more on navigation strategies to create a suitable situation model.

Our second research question focused on the navigation outcomes as children's reading time and navigation patterns. First, we examined *reading time* and found no significant differences for the different types of text. This suggests that the children had no orientation problems in the different conditions and the hypertext and hypertext with overview conditions in particular: They did not spend more time reading all of the pages in one particular condition.

We next examined *navigation pattern* and found the children with the shortest navigation patterns to be in the digital text with overview condition. The advantage of having a graphical overview also manifested itself in the two hypertext conditions. Once again, the navigation patterns were shorter for hypertext condition with an overview as opposed to no overview. When provided a clear navigation overview, the children in our study thus revisited fewer pages and were therefore presumably able to focus on the content of the texts more than when no such overview was provided.

Closer inspection of the navigation strategies used by the children in the different conditions indicates that LDT was read most linearly, followed by DTO, HT, and HTO in that order. This result is in line with what we expected while, the increase in flexibility from linear digital text to hypertext and digital text with a navigable overview to hypertext with a navigable overview reduced the linearity or coherence of the children's reading path. Children may thus adopt a less linear reading order when reading hypertext as opposed to linear digital text or digital text with a graphical overview (Madrid et al., 2009). The results with regard to the first ten navigation clicks show the overview conditions to also be read less linearly compared to conditions without an overview. To fully understand this finding, the number of pages that the children actually read should be taken into consideration. We found that the children in the linear digital text condition, digital text with overview condition, and hypertext with overview condition to generally read all of the pages during their first ten clicks. However, in the hypertext condition, the children read fewer pages during their first ten navigation clicks but reviewed already read pages more often than the in the other conditions. This suggests that the children in the hypertext condition adopted different navigation strategies than the children in the other conditions due to the absence of an overview. The links in the hypertext limit navigation and mean that it takes more navigation clicks to read all of the pages in the text and to construct the text base. It seems likely that the children reread more pages in the hypertext condition simply because they had to in order to activate new links. It can therefore be tentatively concluded that in the hypertext condition, the children adopted a navigation strategy that was text-driven and that the children in this condition focused more on the links present on each page than on the building of a text base.

In the present research, we also examined the relations between the navigation outcomes and the learning outcomes. A linear relationship was found between the total number of pages visited by the children during their reading and their learning outcomes in the hypertext with overview condition, with those children who visited more pages answering more of the knowledge questions correctly. A quadratic relationship was also found in the hypertext with overview condition such that when the number of visited pages increased to an optimum, the number of hierarchies, first-level concepts, and complexity of the mind maps also increased; further increases in the number of pages visited, however, was associated with mind maps of a reduced quality. Children have to read all relevant pages to comprehend the text, which explains the raising curve. However, children who do not reach the optimum of visited pages may remain longer on fewer pages. This reading behavior may show that the children who visited fewer pages were lacking reading strategies or self-regulated learning strategies that may support their reading behavior. Of special interest is the sloping curve after reaching an optimum of pages. We speculate that children who visited more than the expected optimum show no focused and goal directed reading behavior. This random clicking might indicate that the child is not able to regulate his/her learning or does not have the appropriate reading skills for reading hypertext.

No relations were found in the HT conditions between the linearity of the children's navigation strategies and their learning outcomes. In fact, the children navigated in a highly linear manner in all four of the text conditions as indicated by the linearity scores. It can therefore be concluded that the Dutch secondary school children studied here adopted a highly linear reading strategy for non-print text and even hypertext either with or without an accompanying overview.

Conclusion

The Cognitive Flexibility Theory and the Construction-Integration Model are the theoretical frameworks of this study and more generally of hypertext learning. Our results are in line with both perspectives. They fit into the Construction-Integration Model in that the children showed to integrate new explicit information in both the linear digital text and hypertext condition into their existing mental models. They also fit with the Cognitive Flexibility Theory. This theory gives an explanation of meaningful learning and predicts for hypertext that the possibility for the reader to access information from multiple links and different perspectives may influence the mental model of the reader resulting in a multifaceted mental model and flexible knowledge (Shapiro & Niederhauser, 2004). In line with the Cognitive Flexibility Theory, we found children to show relatively deeper processing in hypertext as opposed to linear digital text conditions presumably because the hypertext and hypertext with overview conditions encouraged the adoption of active reading strategies, which led in turn to the creation of a richer situation model.

The most important finding from the present study is that hypertext and overviews both lead to the creation of richer situation models and a deeper understanding of text by children when measured via mind maps as opposed to MC questions. This finding suggests that the increased difficulty of reading hypertext either with or without an accompanying overview can have beneficial learning effects. The properties of hypertext and the coherence gaps that can arise while reading such text may force readers to adopt alternative reading strategies – reading strategies that promote active reading and somehow prompt readers to engage in relatively deeper processing of the material at hand (Kintsch, 1998). More proficient readers may nevertheless use self-regulated learning strategies with hypertext and focus more on overviews with reduced decision making and hence workload as a result (Niederhauser et al., 2000). However, children must have the appropriate navigation and reading skills. Otherwise, more complex hypertext systems that require these additional reading activities will simply disorient and create cognitive overload (DeStefano & LeFevre, 2007). In line with this, self-regulated learning may play a major role in accounting for differences in children's hypertext comprehension and knowledge gains (Azevedo & Cromley, 2004).

The results of the present study show the analysis of children's mind maps to provide an effective technique for scholarly reading research. Furthermore, well-designed hypertext was clearly found to foster a deep level of information processing and thus enhance children's learning.

Implications for Design and Instruction

One important consideration in designing hypertext is that, maps, outlines, menus and overviews present conceptual relationships and enhance the reader's explicit knowledge. Low-prior knowledge readers benefit from such well-defined and structured hypertext, but highly organized hypertext can make reading passive. However, low-prior knowledge readers should be promoted to active reading and learning (Shapiro & Niederhauser, 2004). This careful consideration between reader skills and hypertext features is the major challenge for authors of hypertext. For children, well-structured and clearly navigable hypertext systems in knowledge domains that are at least somewhat familiar to the reader are called for (Amadieu et al., 2009; Zumbach & Mohraz, 2008).

Furthermore, this study was conducted in a classroom setting. Future research should focus more on independent learning situations. An explanation for the fact that we did not find reading comprehension differences in the four text conditions may be that children had enough time to read the whole document in all four text conditions. Therefore, it might be interesting to present larger hypertext documents to the children and focus more on the mental models and situation models of the reader to find differences between children's reading comprehension.

Future Research

In future studies, more advanced methodologies should be used to analyze the strategies used by children to read hypertext. Eye-tracking studies could help clarify the role of reading strategy in the comprehension of hypertext. Gaze data and fixation times could also shed light on the interplay between reading strategies and navigation strategies as well as indications of disorientation and their causes. Relating such measures to the drawing of mind maps may also shed more light on the rather large standard deviations in the different mind map measures in our study. Given that a great deal of individual variation was found in our study, future research should consider less skilled readers in order to examine the cognitive constraints on hypertext comprehension (Merdivan & Özdener, 2011). Our results show that reading hypertext increases cognitive flexibility and the importance of executive function as well as self-regulated learning in hypertext reading. Hypertext may produce added complexity and decrease learning if readers do not regulate their learning (Shapiro & Niederhauser, 2004). Therefore, it remains to be investigated how to teach children this skills for hypertext reading to improve their navigation behavior, which contribute to the understanding and learning from hypertext. Children currently read and learn from the Internet at a very early age, which means that future research should also examine the effects of hypertext comprehension interventions on young children's learning.

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Appendix

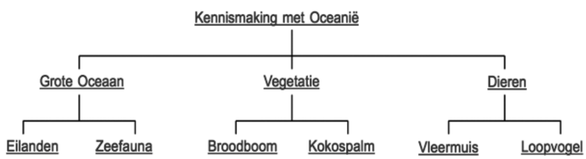
De broodboom

De broodboom, al heel lang ingeburgerd in Oceanië, kan een hoogte van 15 tot 20 meter bereiken. Zijn vruchten zijn groot en kunnen wel 5 kilogram wegen. Ze zijn rijk aan zetmeel en vitamine A en B. Onder gunstige omstandigheden kan een broodboom wel duizend vruchten per jaar dragen en dit zo'n vijftig jaar volhouden. In jonge broodvruchten is het vruchtvlees vast, melig en sterk latexhoudend; rijpend wordt het vezelig, sappig, zacht en uiteindelijk puddingachtig. Gebakken in de oven smaken deze vruchten naar kastanje. Deze boomsoort vormt een belangrijke voedingsbron voor de bewoners van Oceanië.

Vorige pagina Volgende pagina

6 / 11

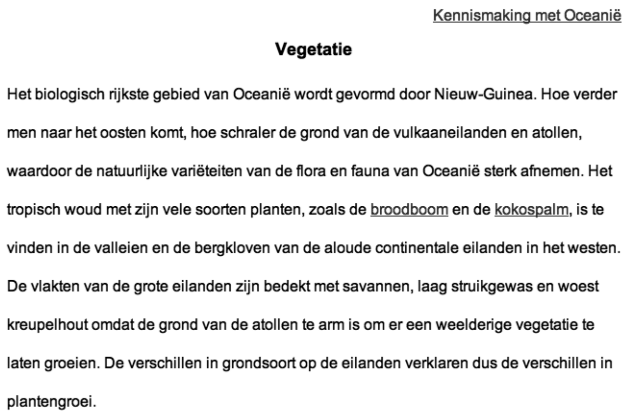
Figure A1 Screen capture from a linear digital text (LDT).



De broodboom

De broodboom, al heel lang ingeburgerd in Oceanië, kan een hoogte van 15 tot 20 meter bereiken. Zijn vruchten zijn groot en kunnen wel 5 kilogram wegen. Ze zijn rijk aan zetmeel en vitamine A en B. Onder gunstige omstandigheden kan een broodboom wel duizend vruchten per jaar dragen en dit zo'n vijftig jaar volhouden. In jonge broodvruchten is het vruchtvlees vast, melig en sterk latexhoudend; rijpend wordt het vezelig, sappig, zacht en uiteindelijk puddingachtig. Gebakken in de oven smaken deze vruchten naar kastanje. Deze boomsoort vormt een belangrijke voedingsbron voor de bewoners van Oceanië.

Figure A2 Screen capture from a digital text with an overview (DTO).

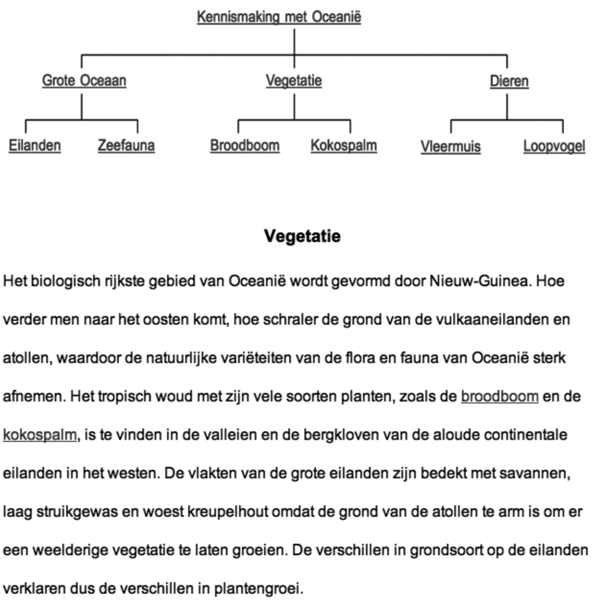


Kennismaking met Oceanië

Vegetatie

Het biologisch rijkste gebied van Oceanië wordt gevormd door Nieuw-Guinea. Hoe verder men naar het oosten komt, hoe schraler de grond van de vulkaaneilanden en atollen, waardoor de natuurlijke variëteiten van de flora en fauna van Oceanië sterk afnemen. Het tropisch woud met zijn vele soorten planten, zoals de broodboom en de kokospalm, is te vinden in de valleien en de bergkloven van de aloude continentale eilanden in het westen. De vlakten van de grote eilanden zijn bedekt met savannen, laag struikgewas en woest kreupelhout omdat de grond van de atollen te arm is om er een weelderige vegetatie te laten groeien. De verschillen in grondsoort op de eilanden verklaren dus de verschillen in plantengroei.

Figure A3 Screen capture from a hypertext (HT).



Kennismaking met Oceanië

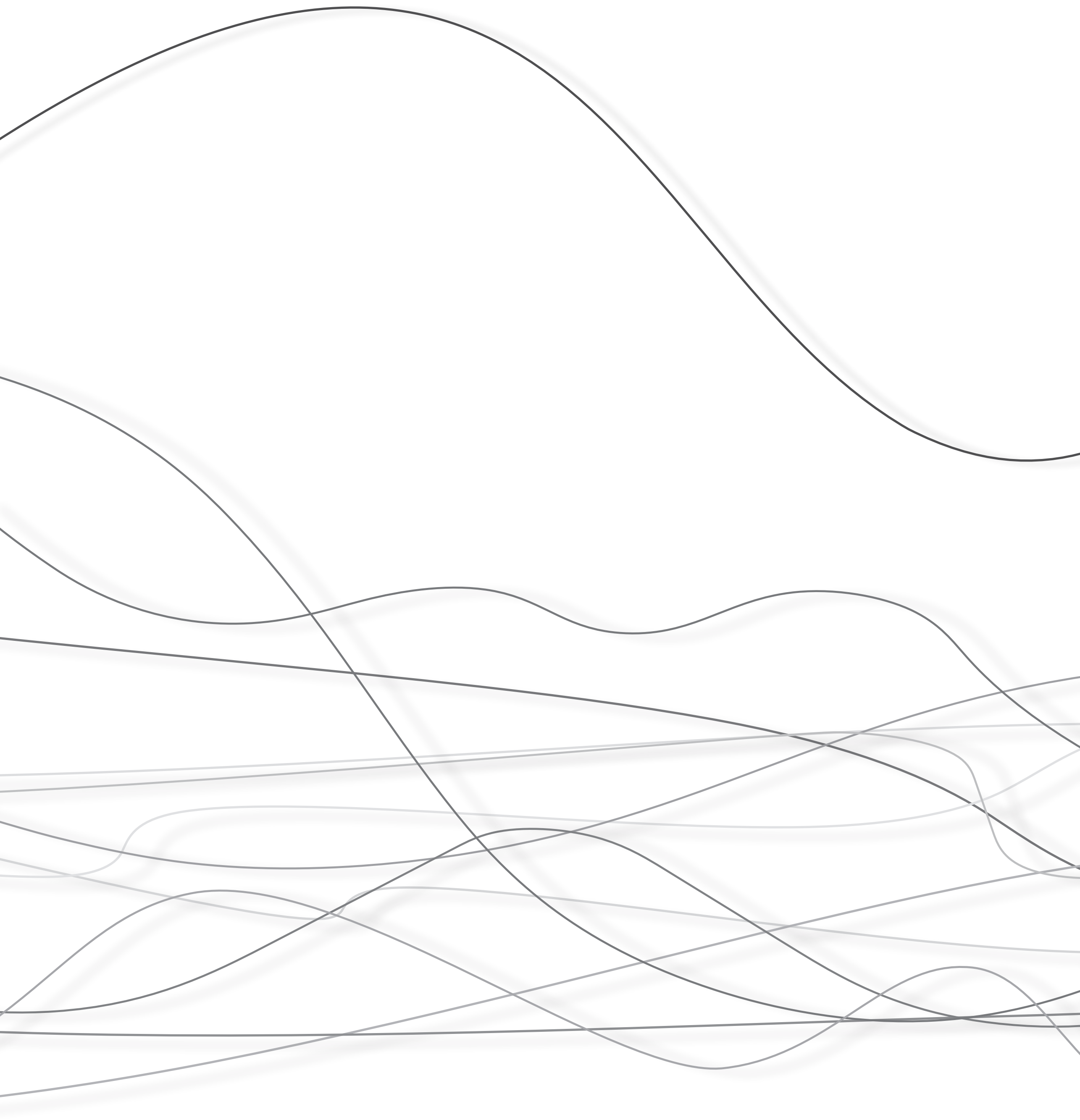
Grote Oceaan Vegetatie Dieren

Eilanden Zeefauna Broodboom Kokospalm Vleermuis Loopvogel

Vegetatie

Het biologisch rijkste gebied van Oceanië wordt gevormd door Nieuw-Guinea. Hoe verder men naar het oosten komt, hoe schraler de grond van de vulkaaneilanden en atollen, waardoor de natuurlijke variëteiten van de flora en fauna van Oceanië sterk afnemen. Het tropisch woud met zijn vele soorten planten, zoals de broodboom en de kokospalm, is te vinden in de valleien en de bergkloven van de aloude continentale eilanden in het westen. De vlakten van de grote eilanden zijn bedekt met savannen, laag struikgewas en woest kreupelhout omdat de grond van de atollen te arm is om er een weelderige vegetatie te laten groeien. De verschillen in grondsoort op de eilanden verklaren dus de verschillen in plantengroei.

Figure A4 Screen capture from a hypertext with an overview (HTO).



Chapter 5

STRATEGY TRAINING and mind mapping facilitates children's digital text comprehension

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Strategy training and mind mapping facilitates children's digital text comprehension.

Abstract

In perspective of literacy skills for the 21st century, children in primary school read hypertext for comprehension. However, children typically are taught reading strategies for linear text, while these strategies are not automatically transferrable one-to-one to hypertext. In the present study, a training group of 55 sixth-graders were taught four hypertext reading strategies (planning, monitoring, evaluation and elaboration) via mind mapping and the usage of a prompting paper-card. A control group of 29 children received no strategy training. We examined to what extent strategy training influenced children's strategy use and learning outcomes: (1) number of pages read and reading time per text, (2) explicit / implicit reading comprehension scores and (3) knowledge representations (relatedness judgment task and mind maps). At posttest, the training group showed higher scores on a self-reported strategy usage questionnaire, higher comprehension scores, and more advanced mind maps as compared to the control group. It can be concluded that hypertext strategy training in combination with mind mapping supports children's hypertext comprehension.

Introduction

Reading hypertexts on the Internet is an important information source in education. The prevalence of hypertext at schools prompts research concerning its' educational usage and implementation (Davis & Neitzel, 2012). Although reading and comprehending hypertext is more challenging for children compared to printed text (Mangen, Walgermo, & Brønnick, 2013; Otter & Johnson, 2000), schools mostly pay attention to the enhancement of reading comprehension by teaching and modeling explicit reading strategies for linear text and not hypertext (Salmerón & García, 2012). Successful adult comprehenders of hypertext, however, use tailored reading strategies to determine a coherent reading order to prevent disorientation and cognitive overload (DeStefano & LeFevre, 2007). Previous studies revealed that strategy training supports hypermedia comprehension in students at college level (Azevedo & Cromley, 2004; Azevedo, Moos, Greene, Winters, & Cromley, 2008). So far, no studies have addressed the effect of hypertext reading strategy training for children. The goal of the present study was thus to examine the effect of such a strategy training on children's hypertext learning outcomes.

Children's Hypertext Comprehension

Even though children are still developing their reading skills and have low-prior knowledge of a topic, they have to construct a text-base level understanding and a coherent situation model in order to successfully comprehend a hypertext (Salmerón & García, 2012). In hypertext, features as hyperlinks and navigable overviews determine the text structure and the interconnectedness of the texts (Foltz, 1992; Salmerón & García, 2012). These features of hypertext allow the reader to determine the reading order, flexibly navigate through the texts and, hence, read more efficiently than in linear text (Salmerón, Kintsch, & Cañas, 2006). A hierarchically structured situation model can only be constructed by making inferences with the integration of the text base and the reader's prior knowledge in a dynamic process (Kintsch, 2005; Salmerón et al., 2006; Zwaan, 1998; Zwaan & Radvansky, 1998).

It is important to note that children can be considered low-prior knowledge readers of a topic and cannot incorporate the information to the knowledge base to the same extent as students or adults. Lawless, Mills, and Brown (2003) compared the navigation patterns of fourth-, fifth-, and sixth-grade children. The results showed that the children generally followed a linear approach in navigating through hypertext and that their navigation patterns were highly related to their level of prior knowledge of a topic. Davis and Neitzel (2012) examined the reader-text interaction of sixth- and seventh-grade children in linear text and hypertext. Results indicated that children approached the hypertext in a linear and static way. In a similar vein, Klois, Segers, and Verhoeven (2013) found secondary school children to mainly show depth-first and linear order navigation behavior in hierarchical hypertext reading.

To resume, in order to become proficient in hypertext reading children need to learn to examine the specific structural features of hypertext, to permanently evaluate the importance and validity of information, and to accordingly adjust their navigation behavior to gain coherence during reading (Akyel & Erçetin, 2009; Amadieu, Tricot, & Mariné, 2010; Azevedo & Cromley, 2004; Naumann, Richter, Christmann, & Groeben, 2008). However, given that children have low-prior knowledge and less cognitive processing capacity (Davis & Neitzel, 2012; DeStefano & LeFevre, 2007), there is the risk of high cognitive load, which puts a high demand on teaching hypertext reading strategies.

Reading Strategies in Hypertext Comprehension

Research has been conducted on reading strategies to support traditional linear text understanding. Comprehension strategies can be defined as specific, learned procedures that foster active, competent, self-regulated, and intentional reading (Block & Pressley, 2001). A theoretical framework for reading strategy instruction in linear text is Zimmerman's (1998) self-regulation model (Spörer, Brunstein, & Kieschke, 2009). This model entails a three steps learning cycle including strategy planning, monitoring, and evaluation or self-assessment. Both in linear text reading and hypertext reading, there is the need for planning strategic actions, monitoring the implementation of the strategies, and evaluating the strategic outcome in a cyclic manner. In addition, a learning strategy, known as elaboration, which is the encoding of knowledge from a text, is crucial for comprehension and learning (Eason, Goldberg, Young, Geist, & Cutting, 2012; Naumann et al., 2008).

Planning and monitoring strategies help the reader to observe the reading process, plan sub-goals and decide about the reading content (Manoli & Papadopoulou, 2012). Therefore, planning of sub-goals, to get an overview and to grasp the macrostructure of a hypertext, is crucial as a decision rule to prevent disorientation and achieve coherence (Foltz, 1992; Salmerón, Kintsch, & Kintsch, 2010). Furthermore, a reader has to monitor the reading process and decide when and how to go back. In hypertext, when planning to read according to a depth-first strategy, a reader first is reading one part of the hierarchy before moving on to other parts, and monitors the reading process to avoid moving out of the current context (Foltz, 1992). To maintain coherence in hypertext, the results of previous research revealed the importance of overview processing and link selection (Salmerón & García, 2011; Salmerón, Cañas, Kintsch, &

Fajardo, 2005). The overview processing strategy seems to be in line with a planning strategy. Research already indicated that the time of overview processing of low-prior knowledge undergraduate-students was positively related to their comprehension, probably because overviews in hypertext provide an organizational framework of the macrostructure for low-prior knowledge readers (Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009; Salmerón & García, 2011). The link selection strategy in hypertext reading seems to be in line with a monitoring strategy in linear text. Indeed, think-aloud protocols showed that better learners adapted more strategic reading in the sense of goal-directed navigation to select goal-relevant information, as well as comprehension-monitoring strategies, compared to poorer learners (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012; Manoli & Papadopoulou, 2012; Ozuru, Dempsey, & McNamara, 2009; Van der Schoot, Vasbinder, Horsley, & Van Lieshout, 2008).

Evaluation and elaboration are reading strategies that focus on information processing in constructing meaning from the text and are crucial for learning. Evaluation strategies help the reader to evaluate the importance of information in hypertext as well as the adjusted strategies. Elaboration strategies support the reader to examine conceptual relationships, and to determine if all important information for comprehension was read (Naumann et al., 2008). During elaboration, the successful reader forms connections between the text and the reader's prior knowledge.

Strategy Training in Hypertext

Reading comprehension strategy instruction, which refers to explicitly prompting strategy usage, applying strategies, and monitor the strategy outcome (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Spörer et al., 2009) may foster children's hypertext comprehension. So far, however, the effect of strategy training in hypertext comprehension has only been investigated in readers at college level (Azevedo & Cromley, 2004; Coiro, 2011; Naumann et al., 2008; Rodicio, Sánchez, Allen, & Acuña, 2013). Azevedo and Cromley (2004) investigated the effects of 30 minutes of self-regulated learning strategy training, based on planning and monitoring, that were tailored to hypermedia features and supported conceptual understanding. This intervention increased deeper understanding and shifts in students situation models compared to a control group (Azevedo & Cromley, 2004). In line with this, Rodicio et al. (2013) showed that undergraduate students who were extensively supported via a set of prompts to plan and monitor during self-regulated learning in a hypertext environment outperformed students with minimal or intermediate support. Naumann et al. (2008) conducted a strategy training with undergraduate students reading hypertext. Students in a cognitive training group were taught organization and elaboration strategies and students in a metacognitive training group received planning and monitoring strategies. The results showed that reading strategies may easily overtax less skilled readers of hypertext (Naumann et al., 2008).

Some recommendations have been posed to train the usage of strategies. For instance, the reading strategies and reading process should not enhance or negatively affect children's cognitive load during reading. First, a stepwise procedure is recommended introducing simple one-by-one strategies before readers use all strategies, to reduce cognitive load (Naumann et al., 2008). Second, Coiro (2011) suggested that digital text comprehension training should follow three phases: modeling, guided practice, and reflection. Teachers who are modeling thoughts and behavior promote children's self-regulation, because it helps children to apply new reading strategies. And finally, reciprocal teaching in small groups appeared to be more effective in teaching reading strategies than instructor-guided strategy training (Spörer et al., 2009).

The implementation of strategy instructions in regular classroom lessons can be optimized by using knowledge mapping, in which children write down their situation model of the text in a mind map. Knowledge maps are spatial representations of concepts, which may represent mental text representations of the reader. Knowledge mapping helps children to remember to apply reading strategies (Brandt et al., 2001; Gurlitt & Renkl, 2010; Tzeng, 2010). Previous research verified a positive effect of knowledge mapping for building a coherent situation model and aiding comprehension (Asan, 2007; Chang, Sung, & Chen, 2002; Chiou, 2008; Karpicke & Blunt, 2011; Klois et al., 2013; Leopold & Leutner, 2012; Tzeng, 2010). Knowledge mapping in the presence of the text is regarded as an elaborative and active learning task (Karpicke & Blunt, 2011). Mind maps seem specifically suited for children, as they give freedom in drawing, are pictorial in nature and focus on associations between concepts (Davies, 2011).

The Present Study

To our knowledge, so far, no previous study examined the effectiveness of strategy training supported by mind mapping in children's hypertext comprehension. The present study aimed to instruct children to use four hypertext reading strategies (planning, monitoring, evaluation, elaboration) via mind mapping. Our main research question was: What is the impact of strategy training on children's strategy usage and learning outcomes? Strategy usage was measured with a self-report questionnaire. Learning outcomes were measured as (1) number of pages read and reading time per text, (2) explicit and implicit reading comprehension scores and (3) knowledge representations in terms of the organization of children's knowledge structures and their drawing of mind maps. We expected positive effects of the intervention on both, strategy usage and learning outcomes.

Method

Design

The present study was designed as a quasi-experimental pretest-posttest design with one group receiving strategy training and one control group. The study was conducted at primary schools, and the classes were random assigned to either the training group or the control group.

Each child read four different hypertexts. These hypertexts were assigned to the children at random; children read two hypertexts at the pretest and two at the posttest. Therefore, four hierarchically structured hypertexts were designed about Oceania, Russia, South America and South Africa (see Appendix, Figure A1). The four hypertexts only differed in content; the number of hyperlinks was the same in all texts as well as the hierarchical structure.

In this study, which is part of a larger data collection, children in the training group read the hypertexts online, using Tobii T120 50 mobile eye-tracker (120 Hz). The screen resolution was 1280 × 1024 pixels. Children from both groups rested on a chin rest during reading a text to reduce their head movements and accordingly data lose. Using a chin rest is common usage and necessary in eye-tracking experiments, to ensure tracker accuracy especially with children (Duchowski, 2007).

Participants

Eighty-nine Dutch 6th-grade children (52 girls, 37 boys) with a mean age of 12 years, from three primary schools in the Netherlands participated. The primary schools were recruited by letter. The social-economical status at the schools was average, and there was a low percentage of children from ethnic minorities. Five children were excluded from analyses, because they were diagnosed with dyslexia. Parents or primary care givers gave their passive consent for the participation of their child in this study. The children in this study had normal or corrected-to-normal vision and did not report any difficulties to read the texts from a computer screen. All children were unfamiliar with the purpose of the experiment.

In the final analyses, 84 children with a mean age of 12 years (50 girls, 34 boys) participated: 55 children in the training group with a mean age of 11 years and 9 month (age range: 11–13 years) and 29 in the control group with a mean age of 12 years and 1 month (age range: 11–13 years). To ensure that all children knew how to work with a computer, children's experience was assessed with a computer experience questionnaire with seven items and a total score of 26 (Citogroep, http://toetswijzer.kennisnet.nl), revealing that all children were experienced with using a computer ($M = 20.35$, $SD = 2.69$). Children's non-verbal Intelligence was within normal ranges ($M = 45.13$, $SD = 6.27$), which was assessed with the Raven's Standard Progressive Matrices (SPM; Raven, Court, & Raven, 1977; updated 2003). Furthermore, we established that children were low-prior knowledge readers of the topic ($M = 5.52$, $SD = 1.77$) assessed with in total 16 multiple choice (MC) questions including four questions per text topic. The two groups of children did not differ in age ($p = .191$). Also, the two groups did not differ in vocabulary ($p = .656$), assessed with a passive vocabulary subtest from the Taaltoets Alle Kinderen (language test for all children; TAK; Verhoeven & Vermeer, 2001) for primary school children. The two groups also did not differ in word decoding skills ($p = .170$, $SD = 12.09$), which were assessed individually with a one-minute word decoding test for children between 7 and 12 years (one minute test; Brus & Voeten, 1973). Finally, the groups did not differ in memory capacity ($p = .146$, $SD = 2.56$), which was assessed with the Digit Span test from the WISC-III-NL (Wechsler Intelligence Scale for Children-III; Wechsler, 1991).

Strategy Training

Table 1 gives an overview of the training schedule of the present study. The reading strategy training was divided into two lessons of one hour each. The lessons were divided into three phases: modeling, guided practice, and reflection (cf. Coiro, 2011).

The first lesson started with a short explanation of hypertext features and introduction on step-wise mind mapping. A sample hypertext was used, and the lesson was supported by a powerpoint presentation. The importance of mind mapping was explained, and the four reading strategies were introduced. A paper-based strategy card was used to externally facilitate the strategy training and as a visual support for the children to memorize the four reading strategies and to prompt strategy usage (see Appendix, Figure A2). The strategy card displayed the four main reading strategies in Dutch: *planning* ("How does the text looks like?"), and *monitoring* ("What do I expect behind the hyperlink?"), *evaluation* ("Is the information important?"), and *elaboration* ("Did I read all the important things?"), one strategy in each corner of the card and visually displayed in different colors. In the middle of the card the mind mapping task was summarized in four steps: 1. Write down all important words, 2. Choose a main term, 3. Choose branches and link the concepts, 4. Make a decent and complete mind map.

During the modeling phase, the instructor modeled and demonstrated when and how to apply which reading strategy. The main idea was to verbalize what a skilled reader is doing and how a skilled reader selects and applies reading strategies. The modeling was elaborated and written down for the first two passages of a training hypertext about microbes in a protocol to accomplish a comparable modeling between schools and classes. Children were asked the appropriate color from their strategy card whenever they recognized a reading strategy. When a strategy was applied, the instructor stopped and gave feedback to the children. This method slows down the reading process and helps children to see how skilled readers apply reading strategies.

During the practice phase, children worked together in groups of two and practiced the strategies. Each dyad worked on one computer. The task was to work together on a mind map of the text in this dyad, supported by the strategy card to relieve cognitive load.

During the reflection phase, at the end of the first lesson, the instructor gave feedback on the mind maps. One good example of a mind map and one poor example of a mind map were chosen from the children's mind maps. The children were asked to explain why the first mind map was regarded as a good example, and give tips to improve the poor mind map.

In lesson two, the strategies on the strategy card were repeated and the four strategies were once more modeled. Next, the practice phase started and children worked in a dyad with someone they had not worked together so far in this training. To support their mind mapping, children prepared parts of the mind map in steps with an exercise sheet, which was related to the four reading strategies (see Appendix, Figure A3). At the reflection phase, again one good mind map of the children's mind maps and one poor mind map was chosen and feedback was given at the class. Children were asked to explain why the first one was a good mind map and give feedback how to improve the second mind map.

Dependent Variables

Strategy usage. To assess children's usage of reading strategies, we developed a reading strategy questionnaire, based on the strategy card used in this study. This questionnaire consisted of seven questions on a five-point scale varying from always (1) to never (5) and refers to the four reading strategies of the strategy card. To do so, the strategies of the strategy card were reworded into statements about the actual use of a strategy (e.g., 'When I read a text on the Internet, I look at the structure of the hypertext'). The two strategies, *monitoring* and *planning*, that were of special importance for hypertext were reworded into respectively three and two statements of the questionnaire. Therefore, the questionnaire consisted of seven statements in total. A pretest scale reliability analysis revealed a sufficient internal consistency of the questionnaire (α = .65). The consistency over time of the questionnaire was also examined. The correlation coefficient of the test-retest analysis revealed a sufficient Pearson correlation of r = .70 (p < .01) for the training group and a moderate correlation for both groups of r = .50 (p < .01). For the analysis of this strategy questionnaire, the scores were rescaled to indicate that high scores show much strategy usage and low scores less strategy usage.

Learning outcomes. ***Number of pages read per text.*** The number of pages read was calculated as the amount of pages activated by clicking on a hyperlink during reading. For the amount of pages read, the number of different pages of the first and second text were calculated and divided by 2 (the number of texts) to receive the mean number of different pages read per text in the pretest. The same calculation was done for the posttest data.

Reading time per text. The reading time was measured as the total reading time from starting at the first page until finished reading. To calculate the reading time per text, the reading time of the first and second text were calculated and divided by 2 (the number of texts).

Reading comprehension. To assess the children's knowledge after reading each hypertext at pre- and posttest, children answered 20 multiple choice (MC) questions with four possible answers of the appropriate text topic (see Klois et al., 2013). The children had to answer the questions after reading a particular text and were not allowed to read again in the text to answer the questions. The MC questions contained 10 explicit questions and 10 implicit questions. The explicit MC questions were related to explicit facts and details mentioned in the text. The implicit MC questions aimed to force the reader to make inferences and to draw conclusions that were not explicitly mentioned in the text. The pretest (N = 84) results showed a good reliability of the explicit MC questions (α = .97) and implicit MC questions (α = .96).

Knowledge representations. We examined the quality of children's knowledge structures with the aid of two distinct approaches. First, with a relatedness-judgment task, based on a pathfinder scaling approach, resulting in pathfinder networks (Clariana & Wallace, 2009; Ifenthaler & Pirnay-Dummer, 2014; Schvaneveldt, 1990). Second, we measured the quality of children's knowledge structures with mind maps that children had to draw with paper and pencil.

Relatedness judgment task. A relatedness judgment task, presented on a computer, (KU-mapper software, Clariana & Wallace, 2009) was used to assess children's knowledge structures. It is assumed that knowledge representations directly tap the organization of a reader's situation model (Clariana & Wallace, 2009). We compared children's knowledge structures with a sequential model and an expert model. In doing so, we can examine directly the effect of the training on children's quality of children's knowledge representations and hence, deeper comprehension.

The 15 most important (Dutch) concept terms, of both, text base and situation model level, of each text topic (4 × 15) used in this study were selected based on their number of frequency as well as meaningfulness for text comprehension. In the relatedness judgment task the participant judges the relatedness of pairs of these 15 concept terms, which were at random presented but pairs of twice the same concept were not rated. The instructions were presented in Dutch on the computer screen. Children had to click on a likert scale on the screen, varying from 'unrelated' (1) to 'highly related' (5) (see, Clariana & Wallace, 2009). We adopted the likert scale of Clariana and Wallace (2009), which originally contained a scale varying from 1 to 9, to a narrow scale of 1 to 5, which we assumed to be more suitable for children. Next, a pathfinder scaling algorithm transforms the matrixes of children's ratings into network structures (Goldsmith, Johnson, & Acton, 1991; Koul, Clariana, & Salehi, 2005; Schvaneveldt, 1990; Trumpower, Sharara, & Goldsmith, 2010). Next, the judgment of each participant and the resulting proximity matrix were compared to a referent to examine the quality of the knowledge structures (Acton, Johnson, & Goldsmith, 1994; Gonzalvo, Cañas, & Bajo, 1994). Children's knowledge structures were compared to a sequential (linear) model and an expert model. Based on the approach of Clariana and Wallace (2009) we converted the four text topics into a sequential model. With the aid of the *ALA-Reader* software we converted the 15 concept terms of each text topic according to their sequential sequence into proximity raw data files and transformed these into pathfinder networks. To compare the children's knowledge structures to a non-sequential model, we calculated for each of the four text topics an average pathfinder network from pair-wise judgments of the 4 undergraduate university students. There is no gold standard yet for the comparison of knowledge structures. However, students are often regarded as expert readers compared to children. The undergraduate university students were informed about their expert role and instructed to achieve expert knowledge structures of the four texts. Furthermore, the experts read the same four texts that were suited for grade six in the same hypertext format as the children of the present study. To motivate the undergraduate university students, they received two European credit points for their participation.

Mind mapping. To assess children's knowledge representations reflecting their situation models of the text, children were asked to draw a mind map. To do so, the children were allowed to read in the hypertext again. Children received no elaborate instructions how to draw a mind map, because the children were familiar with mind mapping. To analyze the mind maps, first, the mind maps were controlled for content, and therefore, associations and concepts outside the scope of the texts were excluded. Second, according to the procedure described in Klois et al. (2013), the *number of concepts* and number of *1st -, 2nd -, 3rd - level concept links* was counted. A hierarchy was built up of at least first and second level concept links (Klois et al., 2013). Next, the *complexity* of the mind maps was determined by scoring the hierarchies according to the scoring system of Evrekli, Ïnel, and Balim (2010). The third level hierarchies of higher order were assigned six points, the second level hierarchies were assigned four points and the first level hierarchies of lower order were assigned two points. A (graduate) educational science student, familiar with mind maps, counted the number of concepts and hierarchies. For this purpose, the student received a standardized scoring manual with explanations and examples beforehand, which were supplemented via oral explanation of the first author. The first author did the second rating (N = 16) to measure the inter-rater agreement *kappa k* of the mind map scoring system. A *kappa* of k = .93 was calculated for the first level concept links and k = 1.00 for the second level indicating perfect agreement between the two raters as well as a *kappa k* = .78 for the third level links, indicating good agreement between the raters.

Text Materials

Pre- and posttest text materials. Two hypertexts at pretest and two hypertexts at posttest were used in the present study. The text materials in the training and control group were the same. For the hypertext materials, linear texts from books suited for this age (The Reader's Digest, 2002) were rewritten into hypertext with hyperlinks. In total four Dutch informative geography texts about Oceania, Russia, South America and South Africa, which were written for this age (see Klois et al., 2013) were random allotted at pretest and posttest.

All four hypertexts had a hierarchical structure: The topic was introduced on the first page, three main chapters followed as well as two subchapters for each main chapter. The texts had a length of 10 pages with Oceania (M = 1014 words), Russia (M = 948 words), South America (M = 984 words), South Africa (M = 941 words). The first page, the index page of the hypertext had a short overview of the subtopics of the next level of the hierarchy. Three main chapters per text topic were presented in the navigable overview on the left hand side and as hyperlinks in the text. The three main chapters contained two links in the overview, each. These overviews represented the last level of the hierarchy. At the subchapters, the overviews linked back to the three main chapters. All links in the overview of the appropriate side were marked as hyperlinks in the text.

All hyperlinks in the texts and in the overviews were presented in blue and underlined. After clicking on the hyperlinks, the color of the activated hyperlinks changed into purple.

Text materials in training sessions. The hypertext of the first training session was about microbes and hierarchically structured with 13 pages (M = 1292 words) and divided into three main chapters and each main chapter was linked to three subchapters. The main chapters and subchapters were presented in an overview on the right hand side on the index page as well as on the top of the page. The subchapters were presented in the overview on the main chapter pages. The main chapters were always presented on the top of each page. In the overview on the top, the page was marked that was open. On the final level of the hierarchy, the overviews of the subchapters linked back to the main chapters. The hypertext of the second training session was about China (M = 1201 words). The hypertext had the same hierarchical structure as the hypertext about microbes except for the overview, which was presented at the bottom of the page. The overview with the main chapters was still presented on the top of the page.

Procedure

Children's individual linguistic and cognitive characteristics were tested beforehand in the training and control groups (see Table 1). The pretest was conducted in 45 minutes. In addition, the strategy-training group received two lessons of hypertext strategy training of 60 minutes each on two separate days. The posttest consisted of two sessions of 45 minutes, conducted on two separate days.

At pretest and posttest, children read two hypertexts. They were instructed to read carefully without time restriction so that they would be able to answer twenty MC comprehension questions after reading each text and without looking back in the text. After reading a hypertext, children first did the relatedness-judgment task. The instructions for the relatedness-judgment task were displayed on the computer screen and the children were instructed to judge the relatedness between the pairs of concepts, which was supplemented via oral explanation. Next, children answered 20 MC comprehension questions. Finally, for the first text of the two texts, they drew a mind map with paper and pencil while being allowed to look back in the hypertext.

Testing was conducted via a carrousel, to reduce the load for the participating schools. After finishing reading, children went to a different room where a laptop was set up for them to perform the relatedness-judgment task, and to answer the MC questions. In this room, they also drew a mind map after reading the first and third text. An undergraduate student assisted and monitored this process.

Table 1 Overview of the Schedule and Activities for the Training and Control Group.

Unit	Training group	Control group	Activities
1	Individual child characteristics	Individual child characteristics	Prior knowledge test; cognitive & linguistic tests
2	Hypertext 1 & 2 at random	Hypertext 1 & 2 at random	Pretest: Measures of strategy usage and learning outcomes
3	Training session 1	-	Modeling, practice & reflection; training strategy card in peer modeling and mind mapping in groups of two
4	Training session 2	-	Modeling, practice & reflection; repetition of strategy card and mind mapping in groups of two
5	Hypertext 3 & 4 at random	Hypertext 3 & 4 at random	Posttest: Measures of strategy usage and learning outcomes

Data Analysis

A series of repeated measures ANCOVA's with Time (pretest, posttest) and Group (control, training) as between subjects variables were performed. To exclude any effect of confounding variables, non-verbal Intelligence and prior knowledge were taken into account in all analyses. They were included as covariates with z-transformation. This strict experimental control allowed to examine between-subjects effects with the dependent variables, and to control for any influence of these variables. For the ANCOVA's partial eta-squared (η^2_p) were calculated with $\eta^2_p = .01$ implicating a small effect, $\eta^2_p = .06$ a medium effect, and $\eta^2_p = .14$ a large effect (Richardson, 2011).

Results

Table 2 shows the descriptive statistics of the dependent variables of the reading activities for the training group and the control group.

Strategy Usage

Regarding the impact of strategy training on children's strategy usage, a repeated measures ANCOVA with Time (pretest, posttest) as within subjects variable and Group (training, control) as between-subject factor on children's strategy usage revealed no significant between-subjects effects for Group, $F(1, 72) = 0.07$, $p = .799$, $\eta^2_p = .00$, Prior Knowledge, $F(1, 72) = 0.51$, $p = .476$, $\eta^2_p = .01$, or Non-verbal Intelligence $F(1, 72) = 0.37$, $p = .546$, $\eta^2_p = .00$. The ANCOVA revealed no main effect for Time, $F(1, 72) = 0.36$, $p \leq .552$, $\eta^2_p = .01$ but a significant interaction effect between Time × Group, $F(1, 71) = 17.98$, $p \leq .001$, $\eta^2_p = .20$, after controlling for the effect of prior knowledge and non-verbal Intelligence. Further exploration of the interaction effect with contrast analysis for pooled within group variance, controlling for the covariates, revealed that children in the training group significantly increased in strategy use at posttest compared to the pretest ($p = .001$, one-tailed). Children in the control group decreased significantly in strategy usage at posttest, compared at pretest ($p = .002$, one-tailed). Pairwise comparisons revealed that the two groups differed significantly at pretest, ($p = .031$) showing that the control group scored higher compared to the training group but not anymore at posttest ($p = .085$). There were no additional significant interactions (all ps > .05).

Table 2 Descriptive Statistics of All Dependent Variables, Strategy Usage, Number of Pages Per Text, and Reading Time Per Page, Reading Comprehension (RC), Similarity (Sequential & Expert Model) and Mind Maps at Pretest and Posttest for Training Group (N = 55) and Control Group (N = 29).

Measure	Training group *M(SD)*	Control group *M(SD)*
Pretest		
Strategy usage	2.64 (0.64)	3.02 (0.58)
N pages per text	9.03 (1.11)	9.25 (0.74)
Reading time per text (min)	9.12 (3.80)	9.58 (4.01)
RC explicit (%)	46.33 (14.60)	41.20 (11.51)
RC implicit (%)	39.80 (12.87)	38.51 (12.99)
Similarity sequential model (%)	21.85 (5.56)	22.23 (5.60)
Similarity expert model (%)	20.22 (6.14)	19.74 (5.59)
Mind maps		
N concepts	17.87 (6.96)	13.66 (5.95)
N hierarchies	9.59 (6.44)	3.97 (4.49)
N concept links		
First level	6.06 (3.34)	8.59 (6.08)
Second level	8.25 (5.42)	3.90 (4.21)
Third level	3.36 (4.28)	1.17 (3.15)
Complexity	65.25 (34.72)	39.79 (24.50)
Posttest		
Strategy usage	2.91 (0.70)	2.68 (0.50)
N pages per text (mean)	9.54 (0.53)	9.43 (0.81)
Reading time per text (min)	10.47 (3.76)	9.06 (3.10)
RC explicit (%)	52.07 (18.36)	40.99(14.85)
RC implicit (%)	39.70 (13.12)	34.01 (14.17)
Similarity sequential model (%)	19.33 (6.09)	18.30 (6.48)
Similarity expert model (%)	17.39 (6.52)	17.95 (7.85)
Mind maps		
N concepts	22.91 (10.84)	11.35 (4.54)
N hierarchies	13.50 (7.28)	4.30 (4.68)
N concept links		
First level	3.83 (1.62)	6.39 (4.08)
Second level	8.79 (3.77)	4.22 (4.56)
Third level	10.29 (10.77)	0.74 (1.54)
Complexity	104.52 (64.91)	34.09 (18.64)

Learning Outcome

Number of pages read per text. A repeated measures ANCOVA of the effect of the training revealed no significant between-subjects effects for Group, $F(1, 71) = 0.04$, $p = .840$, $\eta^2_p = .00$, Prior Knowledge, $F(1, 71) = 0.02$, $p = .878$, $\eta^2_p = .00$, or Non-verbal Intelligence $F(1, 71) = 0.64$, $p = .426$, $\eta^2_p = .01$. A repeated measures ANCOVA of the effect of the training revealed a main effect of Time $F(1, 71) = 9.88$, $p = .002$, $\eta^2_p = .12$, indicating that children read more pages at posttest compared to the number of pages read at pretest. No interaction effect between Time × Group, $F(1, 71) = 2.75$, $p = .102$, $\eta^2_p = .04$, was found after controlling for the effect of prior knowledge and non-verbal Intelligence, revealing no effect of the intervention on the number of pages read per text. Time × Prior Knowledge was a significant interaction, $F(1, 71) = 6.74$, $p = .011$, $\eta^2_p = .09$, indicating that the number of pages read at pre- and posttest was affected by the covariate controlling for children's prior knowledge. There were no additional significant interactions (all ps > .05).

Reading time per text. To examine the effect of the strategy training on children's reading activities, we examined the total reading time per text. A repeated measures ANCOVA of the effect of the training revealed no significant effects of Group, $F(1, 70) = 0.240$, $p = .625$, $\eta^2_p = .00$, and Prior Knowledge, $F(1, 70) = 2.18$, $p = .144$, $\eta^2_p = .03$. The covariate Non-verbal Intelligence was significant related to children's reading time, $F(1, 70) = 4.10$, $p = .047$, $\eta^2_p = .06$, hence, the reading time per text was influenced by children's non-verbal Intelligence. There was no main effect of Time showing that reading time per text did not differ from pre- to posttest, $F(1, 70) = 0.18$, $p = .675$, $\eta^2_p = .00$. Furthermore, there was no interaction effect of Time × Group $F(1, 70) = 0.87$, $p = .356$, $\eta^2_p = .01$, after controlling for the effect of prior knowledge and non-verbal Intelligence and no additional significant interactions (all Fs < 1; ps > .05).

Reading comprehension. To examine the impact of strategy training on children's reading comprehension, a repeated measures ANCOVA with Time (pretest, posttest) × Question Type (explicit, implicit) as within-subjects factors and Group (training, control) as between-subjects factor was conducted on children's reading comprehension scores.

A repeated measures ANCOVA of the effect of the training revealed no significant effects of Group, $F(1, 77) = 1.95$, $p = .166$, $\eta^2_p = .03$, and Prior Knowledge, $F(1, 77) = 0.62$, $p = .432$, $\eta^2_p = .01$. There covariate Non-verbal Intelligence, $F(1, 77) = 9.42$, $p = .003$, $\eta^2_p = .11$, was significant related to children's reading comprehension, indicating that reading comprehension was influenced by non-verbal Intelligence.

By taking account of the confounding variables, the results revealed a main effect of Question Type, $F(1, 77) = 29.81$, $p \leq .001$, $\eta^2_p = .28$, indicating that, overall, children answered more explicit than implicit questions correct. The results revealed a significant interaction effect between Time × Group, $F(1, 77) = 5.12$, $p = .026$, $\eta^2_p = .06$, after controlling for the effect of prior knowledge and non-verbal Intelligence. no significant interaction between Question Type × Group $F(1, 77) = 3.73$, $p = .057$, $\eta^2_p = .05$. We found no main effect of Time, $F(1, 77) = 0.05$, $p = .820$, $\eta^2_p = .00$, and no further significant interactions (all ps > .05). The Time × Group interaction can be explained by the fact that, overall, the training group scored higher than the control group at posttest ($p = .029$), and not at pretest ($p = .984$). Contrast analysis for pooled within group variance revealed that children in the training group significantly increased in overall reading comprehension from pre- to posttest ($p = .026$, one-tailed); the control group did not change from pre- to posttest ($p = .063$, one-tailed).

Knowledge representations. ***Relatedness-judgment task.*** With regards to children's knowledge representation, a repeated measures ANCOVA with Time (pretest, posttest) × Model (sequential, expert) as within-subjects factors and Group (training, control) as between-subjects factor was conducted on children's similarity data of their knowledge representations.

A repeated measures ANCOVA of the effect of the training revealed no significant effects of Group, $F(1, 63) = 0.00$, $p = .956$, $\eta^2_p = .00$, Prior Knowledge, $F(1, 63) = 0.81$, $p = .372$, $\eta^2_p = .01$, and Non-verbal Intelligence, $F(1, 63) = 1.16$, $p = .286$, $\eta^2_p = .02$. The two groups did not differ in overall similarity, and there was no effect of prior knowledge and non-verbal Intelligence on children's similarity of knowledge representations.

The repeated measures ANCOVA revealed a significant main effect of Time $F(1, 63) = 7.81$, $p = .007$, $\eta^2_p = .11$, showing that children had overall more similarity with the two models at pretest compared to the posttest. The results also showed a main effect of Model, $F(1, 63) = 11.29$, $p = .001$, $\eta^2_p = .15$, revealing that children had overall more similarity with the sequential model compared to the expert model. The analysis revealed only one interaction effect between Model × Non-verbal Intelligence, $F(1, 63) = 6.15$, $p = .016$, $\eta^2_p = .09$. There were no other significant interactions (all ps > .05).

Mind maps. We examined children's paper mind maps by looking at the dependent variables: *number of concepts*, *number of hierarchies* and *number of first*, *second* and *third level links* as well as *complexity* of the mind maps. Table 2 shows the means and standard deviations.

Regarding the *number of concepts*, a repeated measures ANCOVA revealed a significant effect of Group, $F(1, 60) = 12.65$, $p = .001$, $\eta^2_p = .17$, and Non-verbal Intelligence, $F(1, 60) = 7.65$, $p = .008$, $\eta^2_p = .11$. These results suggest that the training group used more numbers of concepts compared to the control group. Furthermore, children's non-verbal Intelligence affected the number of concepts in the mind maps positively. There was no significant effect of Prior Knowledge, $F(1, 60) = 0.02$, $p = .905$, $\eta^2_p = .00$.

The ANCOVA showed no main effect of Time on *number of concepts*, $F(1, 60) = 2.53$, $p = .117$, $\eta^2_p = .04$, the number of concepts did not differ at pre- and posttest. Next, the results revealed a significant interaction effect between Time × Group, $F(1, 60) = 4.18$, $p = .045$, $\eta^2_p = .07$, after controlling for the effect of prior knowledge and non-verbal Intelligence. Contrast analysis for pooled within group variance revealed that the training group significantly increased in number of concepts from pre- to posttest ($p = .001$, one-tailed), while the control group did not increase ($p = .345$, one-tailed). Pairwise comparisons showed that the training group used more numbers of concepts at pretest ($p = .044$) as well as at posttest ($p = .001$). There were no additional significant interactions (ps > .05).

Regarding the *number of hierarchies*, a repeated measures ANCOVA revealed a significant effect of Group, $F(1, 60) = 21.33$, $p \leq .001$, $\eta^2_p = .26$, children in the training group drew more hierarchies compared to the control group, and Non-verbal Intelligence, $F(1, 60) = 13.21$, $p = .001$, $\eta^2_p = .18$. There was no significant between-subjects effect of Prior Knowledge, $F(1, 60) = 0.32$, $p = .574$, $\eta^2_p = .01$. The ANCOVA of the *number of hierarchies* revealed a main effect of Time, $F(1, 60) = 8.30$, $p = .005$, $\eta^2_p = .12$, showing that children drew more hierarchies at the posttest. There was no interaction effect of Time × Group, $F(1, 60) = 0.86$, $p = .358$, $\eta^2_p = .02$. Hence, the number of hierarchies did not differ across time and group. There were no additional significant interactions (ps > .05).

The analysis of number of *first and second level links* showed a significant effect of Group, $F(1, 60) = 4.634$, $p = .035$, $\eta^2_p = .07$, and Non-verbal Intelligence, $F(1, 60) = 5.15$, $p = .027$, $\eta^2_p = .08$ but not for Prior Knowledge, $F(1, 60) = 0.02$, $p = .888$, $\eta^2_p = .00$ on the number first level links and Group, $F(1, 60) = 12.40$, $p = .001$, $\eta^2_p = .17$, and Non-verbal Intelligence, $F(1, 60) = 7.76$, $p = .007$, $\eta^2_p = .11$, but not for Prior Knowledge, $F(1, 60) = 0.05$, $p = .828$, $\eta^2_p = .00$ on the number of *second level links*. Hence, children in the training group used more first and second level links compared to the control group. The analyses of within-subjects effects revealed only one main effect of Time on the number of first level links, $F(1, 60) = 22.33$, $p \leq .001$, $\eta^2_p = .27$, indicating that children drew more first level links at pretest. There was no additional main effects or interaction effects (all ps > .05).

The analysis of *third level of links* revealed again a main effect of groups, $F(1, 60) = 9.74$, $p = .003$, $\eta^2_p = .14$, showing that the training group also included more third level links compared to the control group, and a between-subjects effect of Non-verbal Intelligence, $F(1, 60) = 7.40$, $p = .009$, $\eta^2_p = .11$. The analysis revealed no effect of Prior Knowledge, $F(1, 60) = 1.97$, $p = .848$, $\eta^2_p = .00$.

A main effect was found for Time on the number of third level links, $F(1, 60) = 10.86$, $p = .002$, $\eta^2_p = .15$. The ANCOVA analysis revealed a significant interaction between Time × Group, $F(1, 60) = 7.95$, $p = .007$, $\eta^2_p = .12$. Contrast analysis revealed that groups did not differ at the pretest ($p = .177$), but, the training group included significant more third level links at posttest in the mind maps ($p = .002$) compared to the control group. However, contrast analysis for pooled within group variance revealed that in the training group the number of third level links significantly increased from pre- to posttest ($p \leq .001$, one-tailed), but the number of third level links in the control group did not increase ($p = .469$, one-tailed). The analyses revealed no additional significant interactions (ps > .05).

Regarding the *complexity* of children's mind maps, again, the results revealed a main effect of groups, $F(1, 60) = 14.94$, $p \leq .001$, $\eta^2_p = .20$, indicating that the training group drew more complex mind maps compared to the control group and a between-subjects effect of Non-verbal Intelligence, $F(1, 60) = 10.14$, $p = .002$, $\eta^2_p = .15$. The analysis revealed no effect of Prior Knowledge, $F(1, 60) = 9.34$, $p = .949$, $\eta^2_p = .00$. A main effect was found for Time, $F(1, 60) = 9.01$, $p = .004$, $\eta^2_p = .13$. The ANCOVA analysis revealed a significant interaction between Time × Group, $F(1, 60) = 6.58$, $p = .013$, $\eta^2_p = .10$, after controlling for the effect of prior knowledge and non-verbal Intelligence. Post hoc analysis revealed that groups differed at the pretest ($p = .022$) as well as at posttest ($p \leq .001$). However, contrast analysis for pooled within group variance revealed that in the training group the complexity of the mind maps significantly increased from pre- to posttest ($p \leq .001$, one-tailed), but not in the control group ($p = .471$, one-tailed). The analyses revealed no additional significant interactions (ps > .05).

Discussion

The main objective of the present study was to investigate the effectiveness of a strategy training in combination with mind mapping on sixth-grade primary school children's hypertext comprehension, comparing a strategy-training group and a control group. In regular classroom lessons, a strategy training can be optimized by mind mapping because it helps children to apply reading strategies during the training. It is regarded as an elaborative and active learning task (Brandt et al., 2001; Gurlitt & Renkl, 2010; Karpicke & Blunt, 2011; Tzeng, 2010). We examined the impact of a hypertext strategy training and mind mapping on children's strategy use and learning outcomes as measured by the numbers of pages read and reading times per text, explicit and implicit reading comprehension scores, as well as knowledge representations in terms of relatedness judgments and mind maps.

As expected, children in the training group retrospectively reported significantly more strategy use at posttest compared to strategies at pretest, with a large effect size (η^2_p = .20). These results are in accordance with previous reading strategy research, which is based on participant's self-reports during the reading process (Bannert et al., 2009; Manoli & Papadopoulou, 2012). The increase in self-reported strategy use indicated that children increased in metacognitive awareness and behavior (Bannert et al., 2009; Coiro, 2011).

The behavioral learning outcomes, reflected in numbers of pages read and reading times per text, revealed no differences between the training group and the control group. This is probably due to ceiling effects, as children on average read more than 9 of the 10 pages. The hypertext of the present study was hierarchically structured and closed to prevent an artificial high cognitive load on the part of the low-prior knowledge children (DeStefano & LeFevre, 2007). It might well be the case that in a networked structured hypertext environment, the effects of a strategy training on amount of different pages as well as reading times would have been found. It should be noted, however, that a networked and open hypertext environments may have induced extra cognitive load on the children next to the strategy training inducing (DeStefano & LeFevre, 2007).

With regard to reading comprehension, children in the strategy-training group increased in comprehension measured after reading with MC questions. Children showed more comprehension due to the strategy training, when controlled for prior knowledge and non-verbal Intelligence; the obtained effect size was of medium size (η^2_p = .06). It should be mentioned that the choice of reading comprehension tasks may affect the amount of memory involved, because reading comprehension can be measured *during* or *after* reading a text (Magliano, Millis, Ozuru, & McNamara, 2007). However, when naturalistic and unprompted learning activities and navigation behavior in hypertext are measured, the reading comprehension task may guide the reading process, especially when children answer comprehension questions during reading and search for answers in the text. Therefore, comprehension measures after reading are more appropriate in the present study. Given the fact that children answered the comprehension questions after reading, the learning activities were not influenced or guided by the comprehension questions, which rules out any effects of the comprehension task in the present study.

The present study revealed that children in the hypertext strategy-training group gained statistically more knowledge. This finding is consistent with previous research with adult readers, which indicates that hypertext readers who are provided with tailored reading strategies show significant improvements in hypertext reading comprehension (Naumann et al., 2008). However, compared to a metacognitive training with adults of Bannert et al. (2009), who only found learning outcomes on a transfer task that reflected deeper learning, the present strategy training showed overall increased learning in children. Apparently, children need these basic hypertext strategies in hypertext to gain understanding.

The final dependent measure was deeper comprehension reflected in the quality of the knowledge representations. This was assessed via two approaches after reading: Via comparisons of similarity of children's knowledge representations with a sequential model and an expert model, and second, via paper-based mind maps that children have drawn. With regard to the relatedness-judgment task and the impact of strategy training on this measurement of children's knowledge representations, the results showed no effect of the strategy training in combination with a mind mapping task. Children in both groups had overall more similarity with the sequential model, reflected in a large effect size (η^2_p = .11) and can partly be attributed to the increase in reading comprehension on the text-base level (Larkin & Simon, 1987). This text-base level, according to the construction-integration model is typically sequentially structured and for this reason, the knowledge representations of the children in this study show more sequential knowledge representations (Kintsch, 2005; Larkin & Simon, 1987).

With regard to the effect of strategy training on children's mind maps, the results obtained large effect sizes and revealed that children in the training group showed more advanced mental models after reading, reflected in more concepts used (η^2_p = .07), and number of third level links at posttest (η^2_p = .12). In addition, children in the training group draw more complex mind maps at posttest, compared to the pretest and control group (η^2_p = .10). These results are consistent with other studies with adolescents (Azevedo et al., 2008) and low-prior knowledge students (Klois et al., 2013). A strategy training with a mind mapping task is regarded as an elaborative and active learning task, in addition to the four reading strategies developed for hypertext in the present study (Brandt et al., 2001; Gurlitt & Renkl, 2010; Karpicke & Blunt, 2011; Tzeng, 2010). For this reason, mind mapping in hypertext may prompt text structure understanding (Chang et al., 2002; Tzeng, 2010). In line with previous research, children in the strategy training draw more complex mind maps after reading the text and therefore, we assume a small shift in the quality of children's mental models due to the strategy training and mind mapping task (Azevedo et al., 2008).

There are some limitations of the present study that should be acknowledged. First, the learning activities of the children in the present study give no information about their online activities. Think-aloud procedures would be appropriate to examine children's process of strategy usage during hypertext reading (Azevedo et al., 2008; Kang, 2014). Second, the training was very short, only two hours, and did not focus on the reading order and the selection of information (Salmerón & García, 2011). According to Salmerón and García (2011) the amount of information read influences the text base and the reading order the situation model. A longer strategy training may show effects on the quality of children's knowledge representations. Furthermore, a longer strategy training may focus only on the tailored strategy training without mind mapping to exclude any effect of the mind mapping task during the training. Finally, the results of the present study are limited to a hierarchical and closed hypertext environment. A strategy training in a networked hypertext environment may give insight into the strength of a hypertext strategy training for children under high cognitive load.

Future studies may focus examine the effect of strategy training in a networked structured and open hypertext environment. The reading strategies may influence the reading process, especially the reading order in an unstructured hypertext and the reading order may in this case influences the quality of the situation model and therefore, the level of comprehension (Ozuru et al., 2009; Salmerón et al., 2006). We recommend focusing on cognitive and deep process data as number of eye fixations and duration of fixations between text and overview on different hypertext pages. In addition, the assessment of the amount of nodes accessed in total may show navigational shifts due to the strategy training (Naumann et al., 2008; Salmerón et al., 2005). Furthermore, future research could explore the motivation of children to exclude any motivational factor in the data. Interventions could also focus more on promoting text coherence and therefore the reading order and selection of relevant information, to support children to construct a better situation model, reflected in a coherent situation model (Salmerón et al., 2005).

Conclusion

To conclude, we evidenced that children in a very short intervention can be taught to use tailored reading strategies in combination with mind mapping to enhance hypertext comprehension at the outcome level. Tailored strategy training with a mind mapping task in hypertext helps children to improve their hypertext comprehension. The fact that the effects of the training did not transfer to children's quality of knowledge representations can be explained by the shortness of the training. A longer and broader training is necessary to reach an effect on the situation model level. Therefore, teachers should be encouraged to train reading strategies that are tailored to hypertext. At primary schools, explicit strategy training combined with an elaborative and active mind mapping task for hypertext comprehension as part of the reading curriculum appears to be promising to help children to comprehend digital texts.

The present study adds to the strategy instruction research in children's hypertext comprehension (Naumann et al., 2008), in the sense that the increase in reading comprehension indicated how hypertext strategy training with mind mapping can be implemented into the reading instruction curriculum (Spörer et al., 2009). This study shows that a short strategy training where the strategies are explicitly prompted and trained with an elaborative and active mind mapping task, tailored to hypertext features, may support children to improve hypertext comprehension.

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Appendix

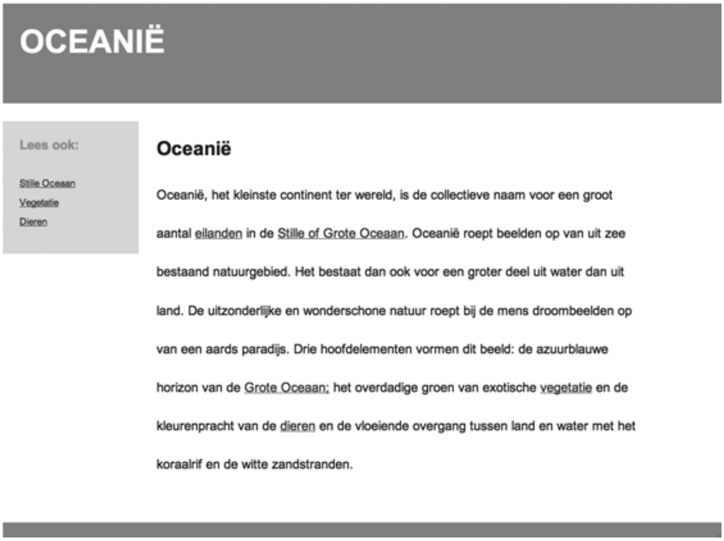


Figure A1 Screen capture from a hypertext used at the pre- and posttest.

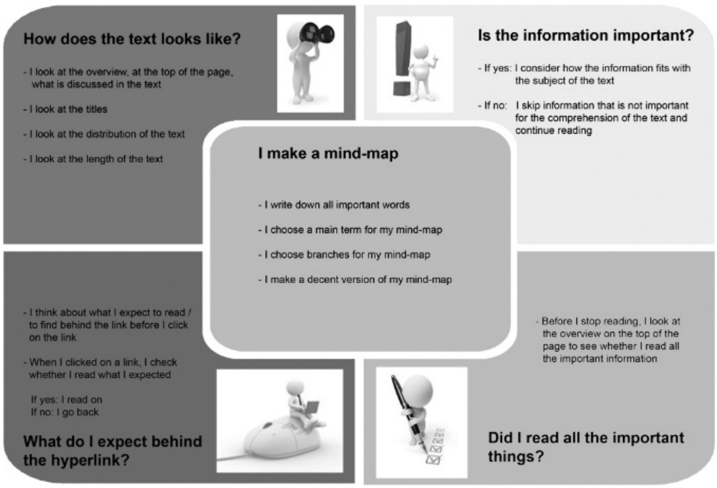
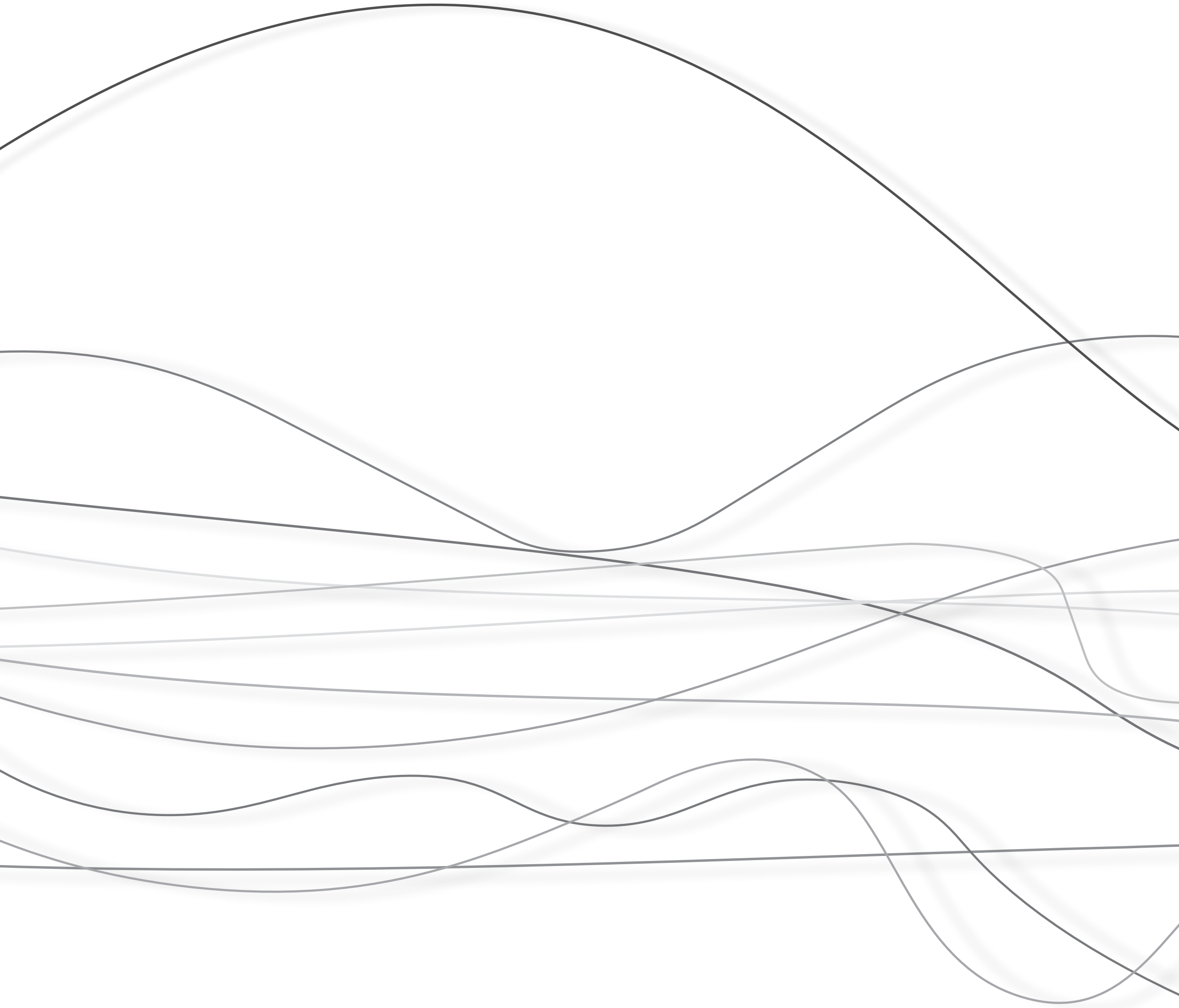


Figure A2 Paper strategy card.

What do I see?	What do I expect behind the hyperlink?	Is the information important?	Did I read all the important things?
Write down the headings and subheadings in this column	*Write down in this column what you expect when you read the title and (sub)headings of this piece of text*	*Write down in this column the information that you think might be important*	*Put a mark in this column when you have read the text and all important links*
China for beginners	This piece of text provides information for people who do not know anything about China	- 10 million km^2 - 1.3 billion people - 6000 years old - Economic growth	x
…			

Figure A3 Exercise sheet of the second training session.

5



Chapter 6

General DISCUSSION

The prevalence and the usage of digital text at schools reveal that the 'new literacy skills and strategies' and the 'new media' are no longer new but already integrated into every day's life. Children use digital texts at school for knowledge acquisition and, hence, have to deal with the features of hypertext to accomplish comprehension and learning from these texts. However, research on digital text comprehension and learning from digital text in children is extremely scarce. Moreover, schools pay attention to the enhancement of reading comprehension by teaching and modeling explicit reading strategies for traditional linear text and not specifically for digital text (Salmerón & García, 2012). To shed more light on this topic, the present thesis examined children's digital text comprehension (Chapter 2, 3) and learning (Chapter 4), with a special focus on hypertext with embedded hyperlinks and graphical and navigable overviews. In the prefinal chapter (Chapter 5), the effectiveness of a strategy training tailored to the hypertext features was examined to measure the effectiveness on the learning outcomes of children. In the present, final chapter, a general discussion on the results of the studies in this thesis is aimed at. A future perspective and educational implications are also given.

Children's Comprehension of Digital Text

Children's reading comprehension was examined in different digital text types. In Chapter 2, children's digital text comprehension was assessed during reading with multiple choice questions. The results showed that children accomplished the same comprehension scores on the text base and situation model level across the various digital text types. This is consistent with previous research with children and adult readers regarding hierarchical hypertext (Amadieu, Tricot, & Mariné, 2010; Salmerón & García, 2012). In line with the findings in the study of Salmerón and García (2012), children at age 11 already showed to be able to successfully read various digital texts.

As can be seen from the results of Chapter 2, Chapter 3, and Chapter 4, the overview did not enhance comprehension, neither on the text-base level nor on the situation model level. The absence of a positive effect of overviews in children's digital text comprehension could be explained in terms of the hierarchical and closed hypertext structure that was used. Salmerón, Baccino, Cañas, Madrid, and Fajardo (2009) found that graphical overviews facilitated comprehension of adult readers only when such overviews are at the beginning of a relatively difficult hypertext. In their study, overviews decreased comprehension when read at the end of relatively easier hypertexts. A hierarchical hypertext, as used in the present thesis, shows a clear macrostructure and gives by itself already a clear structure. This finding makes it clear that children can cope with the mental demands of a hierarchically structured and closed digital text. When reading such a text, they do not need additional structural support in terms of overviews.

Interestingly, the results of the present thesis showed that children's digital reading comprehension measured with multiple choice (MC) questions on the text base and situation model level was the same for linear digital text and hierarchical hypertext with or without overview (Chapters 2, Chapter 3). It was found that digital text does not disadvantage less skilled readers. The results indicated that a hierarchically structured hypertext was suited for children already at primary school to develop and practice digital text reading comprehension.

In Chapter 2 the role of linguistic and cognitive predictors on primary school children's reading comprehension was examined. The results indicated that children's digital text comprehension can be predicted by lexical quality, including linguistic child characteristics of word decoding and vocabulary, regardless of the presence or absence of digital text features (Chapter 2). In line with the lexical quality hypothesis for linear text (Perfetti, 2007), word decoding and vocabulary were also predictors of children's digital text comprehension. Prior knowledge and working memory, in perspective of the cognitive load theory (DeStefano & LeFevre, 2007; Kirschner, Kester, & Corbalan, 2011; Madrid, Van Oostendorp, & Melguizo, 2009) as well as hyperlinks or overviews did not further predict comprehension. The results also supported the assumption, that hierarchical digital text enhances coherence and reduces the amount of necessary working memory resources needed to read in a coherent manner (Amadieu et al., 2010). The results showed that a closed hierarchical hypertext system is also suited for primary school children, given a sufficient level of lexical quality.

The present thesis also examined children's mental text representations in digital text comprehension and compared these to linear digital text. To do so, we investigated the quality of children's knowledge representations in different digital text types (Chapter 3, Chapter 4, Chapter 5). In line with previous research with adults, the quality of primary school children's knowledge representations was examined using pathfinder networks based on a relatedness judgment task (Madrid et al., 2009) in Chapter 3 and Chapter 5. Regarding the quality of children's situation model in digital text, the results indicated that children form a sequential situation model across the various digital text types, and do not accomplish an expert-like situation model. Additionally, it was found that in hypertext, and not in linear digital text, an expert-like situation model predicted children's digital text comprehension (Chapter 3). Madrid et al. (2009) found a tendency of adult readers to show more similarity with expert's networks in hypertext with link suggestions and increased learning.

Children's Learning from Digital Text

The second research question of the present thesis focused on the learning effect of children when reading various digital texts and examined the navigational pattern being followed (Chapter 4). In grade seven, the results showed no differences between the various digital texts. In sixth grade, the results of the comprehension questions indicated overall more text-based learning in hypertext (Chapter 5). The results of the present thesis suggest that children learn equally well in various digital texts (Chapter 4) and younger children learn more on the text-base level and less on the situation model level (Chapter 4, Chapter 5).

Of great interest were the results of Chapter 4 and Chapter 5 regarding children's mind maps. The results of two studies support the assumption that children learn more on the situation model level after reading hypertext (Chapter 4, Chapter 5). Apparently, digital texts with specific hypertext features lead to a deeper reorganization of the cognitive structure measured via mind maps. Meaningful learning from hypertext was evidenced in more flexible and more complex mental representations measured with mind maps. These results were in line with previous findings described in Chapter 3, which showed that an expert-like situation model predicted children's digital text comprehension. Again, the results indicated that a hierarchically structured hypertext is appropriate for children's knowledge acquisition process (Calisir, Eryazici, & Lehto, 2008; Calisir & Gurel, 2003). An advantage of mind mapping above and beyond comprehension questions is that the children's mental models are not guided by the type of questions. Children reproduce their hierarchical or networked mind maps based on the mental model that was stored in memory. It can thus be concluded that the mind mapping method is an effective measure of children's digital text comprehension.

The present thesis also provides new insights into children's navigational pattern in various digital texts. The results of Chapter 4 were the first to show that the navigation behavior of skilled seventh-graders is less linear in hypertext compared to linear digital text. In line with previous research with adults and adolescents, the results support the assumption that the different reader-text interactions resulted in differences in navigational patterns (Madrid et al., 2009), and stress the importance of strategic activities of the reader. Interestingly, the results highlight that in hypertext, the children read fewer pages at the beginning. Instead, children reviewed pages more often, which suggests that children's navigation in hypertext is adapted to the limited navigational possibilities according to a text-driven navigational strategy. The results of Chapter 4 also show a relation between the navigation behavior of the children in the first class of secondary school and their learning outcomes. In hypertext, the number of visited pages was positively related to the learning outcomes until an optimum was reached. Further increase in the number of visited pages beyond the optimum was associated with less learning outcomes. This may be due to less focused and goal directed navigational behavior, which may be put on a par with random clicking. Self-regulated learning can thus be seen as a critical variable to enhance navigational reading strategies in hypertext and support deep comprehension (Azevedo & Cromley, 2004).

Digital Strategy Training in Children

Schools teach explicit reading comprehension strategies for traditional linear text (Salmerón & García, 2012). To make the step to the teaching of digital text comprehension, it is important to know that it has been found that successful adult readers of hypertext use tailored reading strategies to determine a coherent reading order and to prevent disorientation (DeStefano & LeFevre, 2007). In Chapter 3 it was shown that children form sequential knowledge representations, whereas expert-like models predicted hypertext comprehension. In Chapter 4 it was evidenced that more proficient children show deeper learning with hypertext. With this in mind, in Chapter 5, a hypertext strategy training in combination with an elaborative and active mind mapping task for sixth-graders was developed to enhance deeper comprehension in hypertext. Children were trained four hypertext reading strategies and their hypertext learning outcomes were measured. During the training, children were externally regulated and prompted to use reading strategies with a prompting card (Chapter 5).

The results of the present thesis show a positive effect of a hypertext strategy training in combination with a mind mapping task on children's strategy use. Children in the training group retrospectively reported to use more strategies compared to the control group. This let suggest that children increased in (meta) cognitive awareness (Bannert, Hildebrand, & Mengelkamp, 2009; Coiro, 2011).

Regarding the behavioral learning outcomes the hierarchically structured hypertext revealed no differences between the two groups. A networked hypertext environment, which requires more strategic reading, might have uncovered behavioral differences between the two groups. However, with respect to this, it should be noted that a networked hypertext by itself may induce enhanced cognitive load next to the (meta)cognitive strategy training (DeStefano & LeFevre, 2007, Naumann, Richter, Christmann, & Groeben, 2008).

However, the results also provide insights in children's self-produced mind maps. These results highlight amongst others a unique contribution of the mind mapping task for digital text comprehension. The results of Chapter 5 indicate that children in the training group showed more complex mind maps compared to the control group. In addition, in Chapter 3, children showed more similarity with a sequential knowledge structure in hypertext. However, similarity with an expert-like knowledge structure predicted reading comprehension in hypertext. The results of the training in Chapter 5 was in line with the results of Chapter 3, showing that, overall, children in both groups formed more sequential mental models. However, when children's knowledge representations were naturalistic and unprompted measured via mind maps, children in the training group showed more complex mind maps. In line with the assumptions, the mind mapping task supported children to apply reading strategies because the mind mapping task is an elaborative and active learning task (Brandt et al., 2001; Gurlitt & Renkl, 2010). These results are in line with previous research that verified a positive effect of a mapping task for comprehension (Asan, 2007; Leopold & Leutner, 2012). In line with previous research we assume a small shift in the quality of children's mental models due to the strategy training in combination with a mind mapping task (Azevedo, Moos, Greene, Winters, & Cromley, 2008). These findings also makes it clear that children can cope with the mental demands of a hierarchically structured digital text and at the same time can apply externally supported hypertext strategies.

Suggestions for Future Research

The present thesis can only be seen as a first step in examining children's digital text comprehension. The present thesis was the first to measure the quality of children's mental models on the one hand, with a quantitative method to score the mind maps and on the other hand with the aid of a more qualitative method comparing the knowledge structures to linear text and expert knowledge structures. Some limitations apply to the present thesis and the results should not be overgeneralized to networked hypertext or children with high-prior knowledge. One limitation of the present thesis is the relative homogeneity of the population. The present thesis focused on children from upper class of primary school and lower class of secondary school with normal general ability, no developmental reading disorder. Future studies should investigate reading comprehension of hypertexts in various populations.

Another limitation of the present thesis is the text structure of the various digital texts used. Hierarchical digital text and especially hierarchical hypertext already gives an implicit structural support, because the texts are linked to each other to some extent (Amadieu et al., 2010). Therefore, a closed hierarchical text is already by definition more coherent compared to networked structured digital text. Future studies could address children's comprehension of networked hypertext. In line with this, the focus on navigational processes in future studies could give more insight into the reading comprehension as well as learning process of children. However, the navigational behavior of a reader depends to a great extent on the design of the digital texts and hence, can vary from one hypertext to another and complicate a general conclusion (Madrid et al., 2009; Salmerón & García, 2011).

Finally, the positive results of the strategy training of children's deeper learning with hypertext were found by means of a mind mapping task and externally prompted reading strategies. Research revealed that participants with self-regulated learning skills tend to develop more advanced mental models in hypermedia (Azevedo & Cromley, 2004). Therefore, in hypertext comprehension it is important that children learn to supervise their own reading process through self-regulated learning. Future research could examine the balance between the need to support children and the need to encourage a self-directed and more active and self-guided reading behavior in digital texts with a special focus on self-regulated learning.

Practical Implications

The present thesis examined children's digital text comprehension and learning as well as the effect of a hypertext strategy training on children's knowledge acquisition. It can be concluded that a simple, closed, and hierarchical hypertext is suited for children as soon as children have developed a sufficient level of lexical quality. Regarding children's digital text comprehension, lexical quality plays a crucial role. Specifically, decoding and vocabulary as well as working memory and prior knowledge contributed uniquely to the reading comprehension processes of digital text. As soon as children have developed appropriate lexical quality, they comprehend hierarchical structured hypertext as well as linear digital text. Designers of educational hypertext should consider how the hypertext will be used and who will be using it. The present thesis shows the suitability of a hierarchical structure, which may be seen as a guideline for educational hypertext in sixth- and seventh-graders.

Regarding children's learning from digital text, children must be supported to navigate in a coherent manner through the hypertext. Teachers may prevent the children from clicking around and should support the children to navigate relevant pages and to focus on a coherent navigation to enhance learning and support hypertext comprehension. Furthermore, teachers could encourage children to form an expert or teacher-like situation models to support comprehension and deep learning. These expert-like situations models were associated with higher scores of reading comprehension. The teacher may model the knowledge structures of a digital text and support the children to form more teacher-like knowledge structures, reflected in children's mind maps to foster deeper comprehension (cf. Pressley, 2006).

The present thesis shows that hypertext strategy training with an elaborative mind mapping task facilitates children's hypertext reading. Teachers should therefore focus on the specific digital text features during their regular comprehension classes and focus on tailored comprehension strategies. The present thesis also showed that children are able to adjust major digital text strategies in a very short but externally regulated training in combination with an elaborative mind mapping task. To improve learning and enhance deeper understanding, children should be encouraged to use simple hypertext reading strategies as soon as children have developed appropriate lexical quality. Besides the development of lexical quality and linear text comprehension digital text features and the structure of digital text need to be explicitly explained in class to support children becoming proficient hypertext users.

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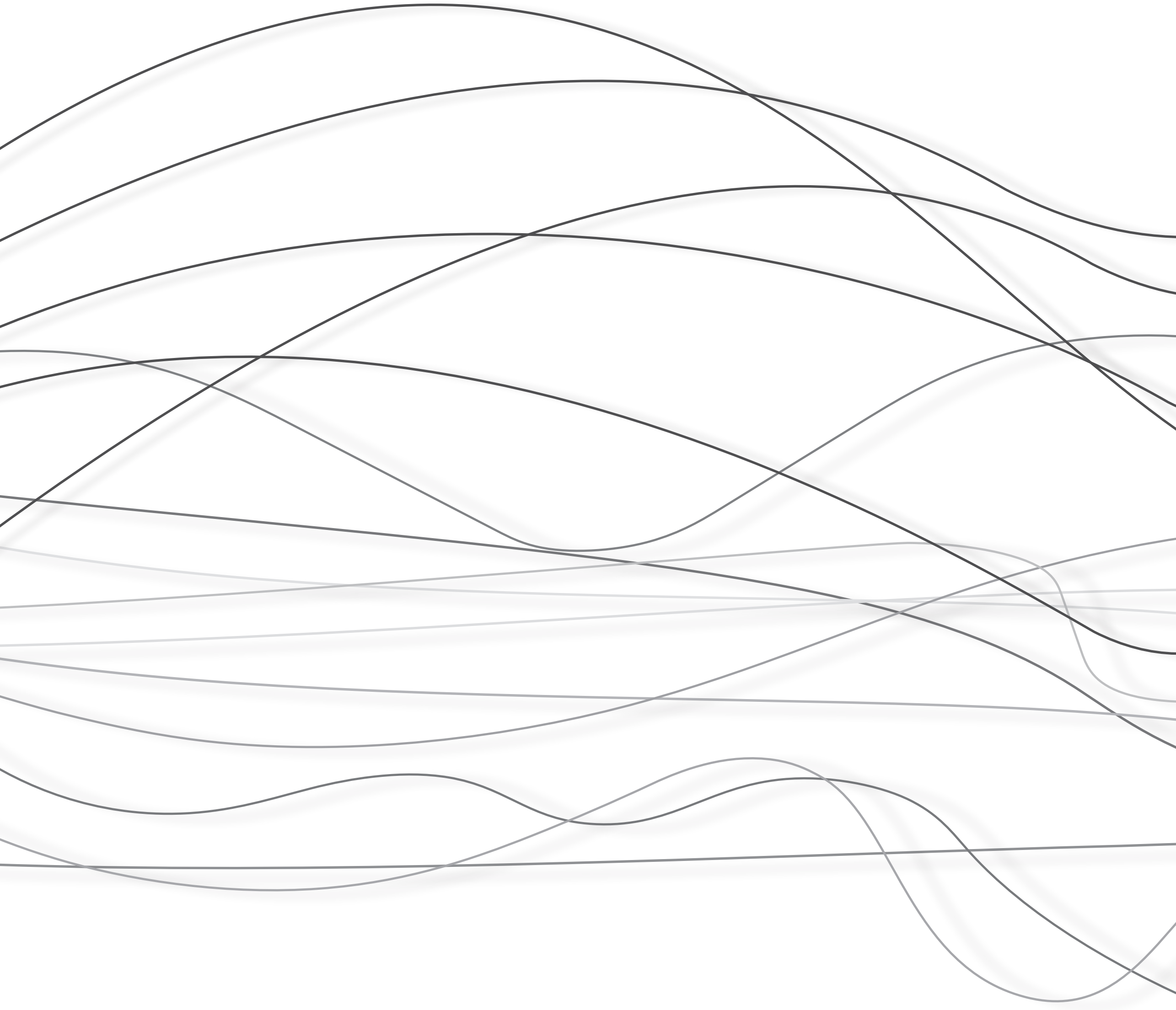

SUMMARY

SAMENVATTING

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CURRICULUM VITAE

Summary

The Internet is used more and more at school and thus, children read digital text for comprehension (Burnett, 2009; Salmerón, Cañas, Kintsch, & Fajardo, 2005). Such digital texts with embedded hyperlinks and graphical or navigable overviews are called hypertext. The text features of such a hypertext cause a nonlinear text structure during reading. Research with adults revealed that forming a coherent knowledge representation from digital text is more challenging compared to linear text (Foltz, 1996). In addition, research also has shown inconsistent results about the relative effectiveness of different digital texts (Amadieu, Tricot, & Mariné, 2010). Research about children's digital text comprehension is rare and it is unclear how children comprehend different digital texts. Therefore, the present thesis aimed to answer three research questions: (1) How do children comprehend digital text types with specific hypertext features (Chapter 2, 3), (2) How do children learn from different digital text types with specific hypertext features (Chapter 4) and (3) how children's learning from hypertext can be fostered (Chapter 5).

Children's digital text comprehension (Chapter 2, 3) and learning (Chapter 4) was examined with four different digital texts: linear digital text (LDT), digital text with navigable graphical overview (DTO), digital text with embedded hyperlinks (hypertext; HT) and hypertext with navigable graphical overview (HTO). In Chapter 2, children's digital text comprehension was assessed *during* reading with multiple choice (MC) questions, whereas in Chapter 4 and Chapter 5, children's learning from digital text was assessed *after* reading with MC questions.

Reading Comprehension and Digital Text Features

According to the lexical quality hypothesis, children have to develop a sufficient level of word decoding and vocabulary in linear text comprehension (Perfetti, 2007). Furthermore, children have to cope with the cognitive demands during reading. Prior knowledge and working memory are crucial to develop reading comprehension and to reduce the cognitive load during reading.

The digital text features as well as the reader characteristics influence the reading process in digital text and hence, the building of a coherent situation model which is the goal of comprehension. The readers' reading skills and prior knowledge (i.e. of the topic) are crucial for successful comprehension of digital text, because they help the reader to prevent disorientation (Amadieu et al., 2010; DeStefano & LeFevre, 2007; Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009). The digital text features may help low prior knowledge readers of the topic, as children are, to enhance determining a coherent reading path during reading.

Thus, hyperlinks and graphical overviews may act as linguistic markers in digital text. But at the same time, researchers have evidenced the risk of cognitive overload in digital text reading, because, these features enhance the flexibility in navigation and may produce added complexity for low prior knowledge readers (Shapiro & Niederhauser, 2004).

Children's Digital Text Comprehension

In Chapter 2, and 3 children from upper classes of primary school were examined. The influence of the digital text features on children's comprehension was investigated. In addition, Chapter 2 focused on individual differences in children and Chapter 3 examined differences in children's mental models. Children accomplished the same comprehension scores across the four digital texts measured with MC questions during reading. The overview did not enhance comprehension, due to the hierarchical and closed hypertext structure, which by itself gives structural information to the reader about the macrostructure of the text (Salmerón et al., 2009). The results presented in Chapter 2 revealed that in line with the lexical quality hypothesis, decoding skills and vocabulary were strong predictors of children's digital comprehension.

In Chapter 3, differences in children's knowledge representations were examined, using a psychometric pathfinder network scaling of relatedness judgment ratings (see also Chapter 5) as well as a mind mapping task (see Chapter 4, 5). The pathfinder methodology allows the calculation of a similarity measure between a knowledge representation of a child and a sequential knowledge representation model as well as the knowledge representation of a child and an expert knowledge representation model. The results of Chapter 3 revealed that children formed sequential knowledge representations in all four text types; however, similarity with an expert model predicted reading comprehension in hypertext with and without overview. The results suggest that reading hypertext with or without overview may foster deeper comprehension.

Children's Learning from Digital Text

In Chapter 4 children from lower classes of secondary school were examined. The influence of the digital text features on children's learning from digital text was studied. The results of Chapter 4 showed that children in the lower classes of secondary school learned equally well from the four digital texts. The results of Chapter 5 showed that children from upper classes of primary school learned more on the text base level from hypertext. Again, these results evidenced the suitability of hierarchical hypertext for children (Calisir, Eryazici, & Lehto, 2008). In addition, Chapter 4 focused on children's navigation in the four digital text types. Children in the lower classes of secondary school navigated less linear in hypertext with or without overview compared to linear text. Furthermore, reading times did not differ between the text types and children learned equally well but formed richer mind maps after reading hypertext with or without overview. The results of Chapter 4 evidence that hypertext may foster a deeper level of information processing and learning, which was also in line with the results from Chapter 3 indicating that expert like knowledge representations predicted hypertext comprehension.

Hypertext Strategy Training

Children learn reading strategies at school that are developed and investigated for linear text, however these are not automatically transferable one-to-one to hypertext (Salmerón & García, 2012). Four main reading strategies (planning, monitoring, evaluation, and elaboration) (Zimmerman, 1998) were developed for hypertext and thought to children in a training, in combination with a mind mapping task. This training was externally regulated with a prompting paper-card that visualized the four reading strategies.

In Chapter 5, the extent of a strategy training on children's strategy use and learning outcomes was investigated. The results showed that at post-test, the training group showed higher scores on self-reported strategy use, higher comprehension scores and more advanced mind maps compared to a control group. In general, the results of Chapter 5 revealed that a short hypertext strategy training with a mind mapping task supports children's hypertext comprehension (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Leopold & Leutner, 2012).

Conclusions and Practical Implications

To conclude, the present thesis shows that children from upper classes of primary school can cope with the mental demands of hierarchical hypertext as far as children have developed a sufficient level of lexical quality. Furthermore, children from lower classes of secondary school learn equally well from various hierarchical digital texts and children from upper classes of primary school learn more on the text base level with hierarchical hypertext. In addition, the present thesis revealed that children can learn to use major digital text strategies in a short externally regulated training in combination with a mind mapping task.

Based on this thesis some practical implications can be given. Designers of educational hypertext should consider the target group of the hypertext. In line with this implication the present thesis evidenced the suitability of a hierarchically structured hypertext as a guideline for children in upper classes of primary school and lower classes of secondary school.

Teachers could encourage children to form an expert or teacher-like situation model to support comprehension and deep learning. To do so, teachers should support the children to navigate in a coherent manner in digital text and model the expert-like knowledge structures (Pressley, 2006). Furthermore, teachers should focus on the specific digital text features in comparison to linear text comprehension and also on tailored comprehension strategies. In general, children should be encouraged to use major hypertext reading strategies.

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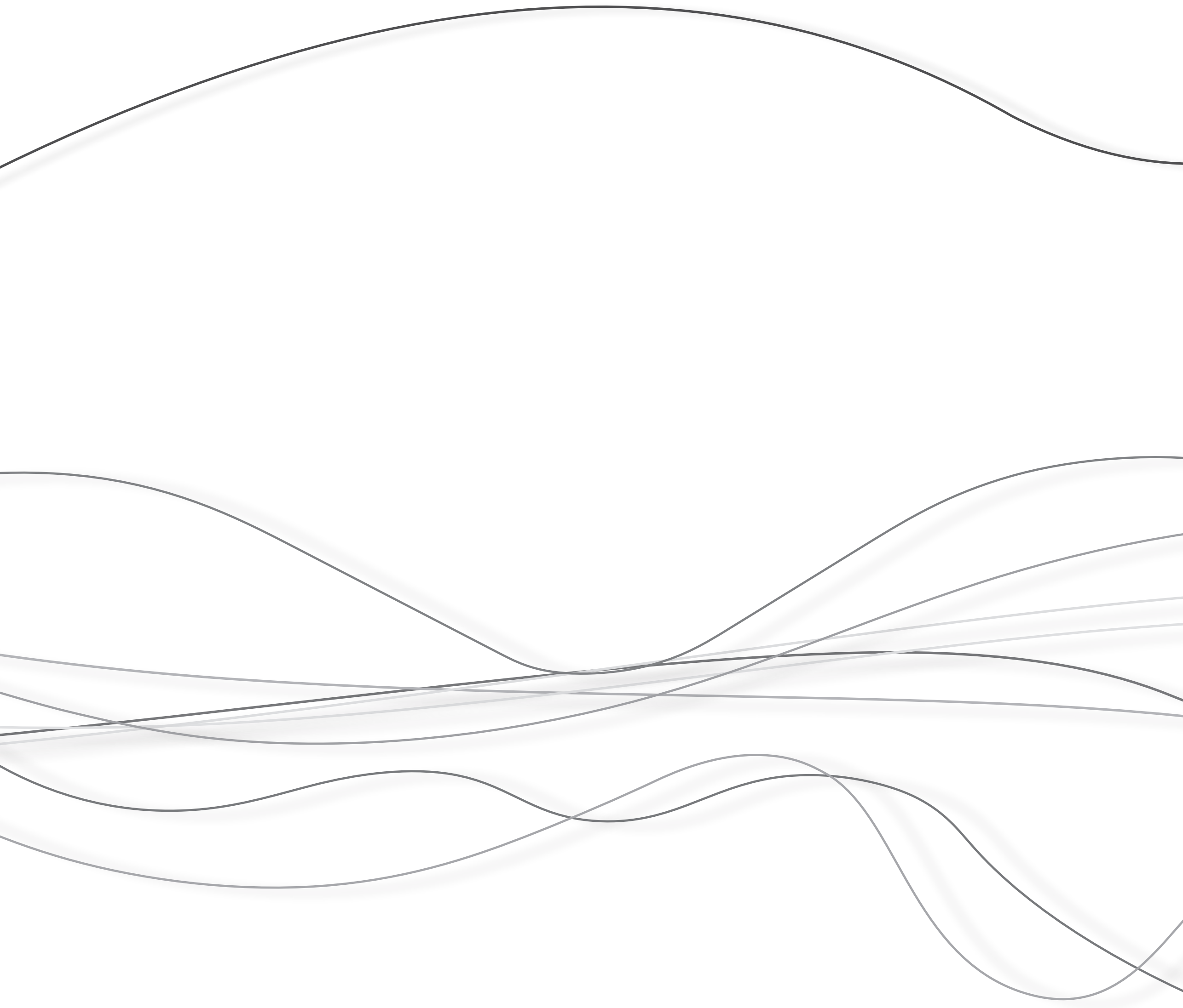

SAMENVATTING

Samenvatting

De implementatie en het gebruik van computers en het Internet maakt dat het belangrijk is voor kinderen om digitale teksten te begrijpen (Burnett, 2009; Salmerón, Cañas, Kintsch, & Fajardo, 2005). Digitale teksten met ingebedde hyperlinks en (grafische) navigatie overzichten worden hypertekst genoemd. De tekstkenmerken van hypertekst kunnen zorgen voor een non-lineaire tekst-structuur tijdens het lezen. Onderzoek met volwassenen lezers heeft aangetoond dat het voor de lezer van hypertekst moeilijker is een coherente kennis representatie te vormen vergeleken met lineaire tekst (Foltz, 1996). Onderzoek met kinderen is echter beperkt en het is tevens onduidelijk hoe kinderen verschillende digitale teksten begrijpen. In dit proefschrift stonden drie hoofdvragen centraal: (1) hoe kinderen verschillende digitale teksten met specifieke hypertekst eigenschappen begrijpen (zie Hoofdstuk 2, 3), (2) hoe kinderen van verschillende digitale teksten met specifieke hypertekst eigenschappen leren (zie Hoofdstuk 4), en (3) hoe het leren van kinderen van hypertekst verhoogd kan worden (zie Hoofdstuk 5).

Het digitale tekstbegrip van kinderen (Hoofdstuk 2, 3) en het leren van digitale teksten (Hoofdstuk 4) werd onderzocht aan de hand van vier verschillende digitale teksten: lineaire digitale tekst (LDT), digitale tekst met grafische overzicht (DTO), digitale tekst met ingebedde hyperlinks (hypertekst; HT) en hypertekst met een grafisch overzicht (HTO). Het digitale tekstbegrip werd onderzocht aan de hand van meerkeuzevragen *tijdens* het lezen in Hoofdstuk 2 en het leren van digitale tekst werd *na* het lezen onderzocht in Hoofdstuk 4 en Hoofdstuk 5.

Tekstbegrip en de Kenmerken van Digitale Tekst

Onderzoek met betrekking tot lineair tekstbegrip heeft aangetoond dat de lezer een voldoende maat van lexicale kwaliteit, waaronder decodeervaardigheden en woordenschat, (Perfetti, 2007) moet ontwikkelen. Bovendien moet de lezer om kunnen gaan met de cognitieve eisen van het lezen. Dus, voorkennis en het werkgeheugen zijn cruciaal in de ontwikkeling van begrijpend lezen en om de cognitieve belasting tijdens het lezen te verminderen.

De kenmerken van digitale tekst evenals de karakteristieken van de lezer beïnvloeden het leesproces in digitale tekst en dus de opbouw van een coherent situatie model. De opbouw van een coherent situatiemodel is cruciaal om een tekst goed te begrijpen. De leesvaardigheid en de voorkennis (bijvoorbeeld over het onderwerp) zijn belangrijke lezer karakteristieken die voorspellend zijn voor succesvol tekstbegrip van digitale tekst, omdat deze eigenschappen de lezer helpen om tijdens het lezen desoriëntatie te voorkomen (Amadieu, Tricot, & Mariné, 2010; DeStefano & LeFevre, 2007; Salmerón, Baccino, Cañas, Madrid, &

Fajardo, 2009). De digitale tekst kenmerken kunnen lezers met weinig voorkennis over het onderwerp, bijvoorbeeld kinderen, helpen een coherent leesvolgorde te bepalen tijdens het lezen. De hyperlinks en grafische overzichten kunnen dus als "linguïstische markers" fungeren in digitale tekst. Echter, onderzoekers hebben aangetoond dat lezers van digitale tekst een groot risico lopen op een cognitieve overbelasting, door de flexibiliteit in het navigatiegedrag. Dit kan met name moeilijkheden veroorzaken voor lezers met weinig voorkennis over het onderwerp (Shapiro & Niederhauser, 2004).

Het Digitale Tekstbegrip van Kinderen

In Hoofdstuk 2 en Hoofdstuk 3 werd de invloed van digitale tekst kenmerken op het tekstbegrip van kinderen in de bovenbouw van de basisschool tijdens het lezen onderzocht. Bovendien ging Hoofdstuk 2 in op individuelle verschillen in het tekstbegrip en Hoofdstuk 3 op verschillen in het mentale model dat kinderen tijdens het lezen vormen. De resultaten in Hoofdstuk 2 en Hoofdstuk 3 lieten zien dat de kinderen niet verschilden in tekstbegrip tussen de vier digitale teksten, gemeten met meerkeuzevragen tijdens het lezen en dat een grafisch overzicht het tekstbegrip niet verhoogde. De hiërarchische en gesloten hypertekst structuur geeft dus zelf voldoende structurele informatie voor de lezer over de macrostructuur van de tekst (Salmerón et al., 2009). Uit de resultaten van Hoofdstuk 2 is gebleken dat in lijn met de lexicale kwaliteit hypothese (Perfetti, 2007), technisch lezen en woordenschat de belangrijkste voorspellers waren van het digitale tekstbegrip van kinderen.

In Hoofdstuk 3 werden de verschillen in de kennis representaties van de kinderen onderzocht aan de hand van een psychometrisch pathfinder network dat een inschatting maakt op basis van oordelen over samenhang (zie ook Hoofdstuk 4) evenals een woord-web taak (zie Hoofdstuk 4, 5). De pathfinder methodiek maakt een berekening van een "similarity maat" met een model dat uitgaat van een sequentiële kennis representatie en een model dat de kennis van deskundigen representeert. Uit de resultaten van Hoofdstuk 3 is gebleken dat kinderen een sequentiële kennis representatie vormen in alle vier verschillende soorten van digitale teksten. Echter, overeenkomst met het deskundige model was een belangrijke voorspeller voor tekstbegrip in hypertekst met en zonder overzicht. Deze resultaten suggereren dat het lezen van hypertekst met of zonder overzicht dieper tekstbegrip kan bevorderen.

Leren van Digitale Tekst

In Hoofdstuk 4 werd de invloed van digitale tekst kenmerken op het leren van kinderen in de onderbouw van het voortgezet onderwijs onderzocht. De resultaten van Hoofdstuk 4 lieten zien dat de kinderen in de lagere klassen van de middelbare school even veel van de vier digitale teksten leerden. In Hoofdstuk 5 werd aangetoond dat kinderen in de bovenbouw van de basisschool meer expliciete informatie leren met hypertext. Dit toonde nogmaals de geschiktheid van hiërarchische hypertekst voor kinderen aan (Calisir, Eryazici, & Lehto, 2008). Bovendien ging Hoofdstuk 4 in op verschillen in het navigatiegedrag in de vier digitale teksten. Kinderen in de lagere klassen van het voortgezet onderwijs navigeerden minder lineair in hypertekst met of zonder overzicht dan in de lineaire digitale tekst. De leestijd verschilde niet tussen de vier digitale teksttypes en de kinderen leerden even goed maar vormden kwalitatief betere woord-webs na het lezen van hypertekst met of zonder overzicht. De resultaten van Hoofdstuk 4 tonen aan dat kinderen in digitale tekst met hyperlinks de informatie dieper verwerken.

Hypertekst Strategie Training

Kinderen leren lees-strategieën op school die ontwikkeld en onderzocht zijn voor lineaire tekst, maar deze kunnen niet automatisch één-op-één overgedragen worden voor het lezen en begrijpen van hypertekst (Salmerón & García, 2012). Vier belangrijke lees-strategieën (plannen, monitoren, evalueren en elaboratie) (Zimmerman, 1998) werden geïdentificeerd en aan de kinderen in een training in combinatie met een woord-web taak geleerd, specifiek voor hypertekst. Deze training werd extern gereguleerd met een geheugensteuntje; een kaart waarop de vier strategieën visueel waren weergegeven.

In Hoofdstuk 5 werd het effect van een strategie training op het strategie-gebruik en de leesresultaten van de kinderen onderzocht. De resultaten toonden aan dat de trainingsgroep na afloop van de training hogere scores op het zelf gerapporteerde gebruik van de strategieën had. Bovendien liet de trainingsgroep hogere tekstbegrip scores zien en meer geavanceerde woord-webs, vergeleken met de controlegroep. In het algemeen laten de resultaten van Hoofdstuk 5 zien dat een korte hypertekst strategie training met een woord-web taak het hypertekst begrip van kinderen ondersteunt (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Leopold & Leutner, 2012).

Conclusie en Implicaties voor de Praktijk

Op basis van het uitgevoerde onderzoek van dit proefschrift werd aangetoond dat kinderen in het basisonderwijs met de mentale eisen van een hiërarchisch gestructureerde digitale tekst om kunnen gaan. Tevens kunnen de kinderen even goed verschillende hiërarchische digitale teksten begrijpen waarbij een voldoende mate van lexicale kwaliteit een belangrijke voorwaarde is (Hoofdstuk 2; Amadieu, Tricot, & Mariné, 2010; Salmerón & García, 2012). Een hiërarchische digitale tekst ondersteunt de coherentie in de tekst en vermindert derhalve de invloed van het werkgeheugen (DeStefano & LeFevre, 2007). Tevens laat dit proefschrift zien dat kinderen van de bovenbouw van de basisschool meer expliciete informatie leren in hypertekst en kinderen van de middelbare school even goed van verschillende hiërarchische digitale teksten leren. Bovendien laten de resultaten van dit proefschrift zien dat kinderen aan de hand van een kort training in staat zijn hypertekst strategieën die extern gereguleerd zijn in combinatie met een woord-web taak te leren en te gebruiken om hun tekstbegrip te verhogen.

Op basis van de resultaten van dit proefschrift kunnen enkele praktische implicaties worden gegeven. Allereerst is het voor ontwerpers van educatieve hypertekst belangrijk de doelgroep van de digitale tekst tijdens het ontwerp voor ogen te houden. In lijn met deze implicatie heeft dit proefschrift de geschiktheid van een hiërarchisch gestructureerde hypertekst aangetoond voor kinderen in de bovenbouw van het basisonderwijs en de onderbouw van het voortgezet onderwijs. Voor leerkrachten kan op basis van dit proefschrift de praktische implicatie gegeven worden, dat leerkrachten de kinderen zouden kunnen ondersteunen om coherent in een digitale tekst te navigeren, bijvoorbeeld door het modellen van de coherente navigatie pad (Pressley, 2006). Verder is het aan te bevelen dat leraren hun onderwijs ook op de kenmerken van digitale tekst richten in vergelijking met lineaire tekst evenals op specifieke hypertekst strategieën. Over het algemeen moeten kinderen worden aangemoedigd door de leerkracht om hypertekst lees-strategieën tijdens het lezen van digitale tekst te gebruiken.

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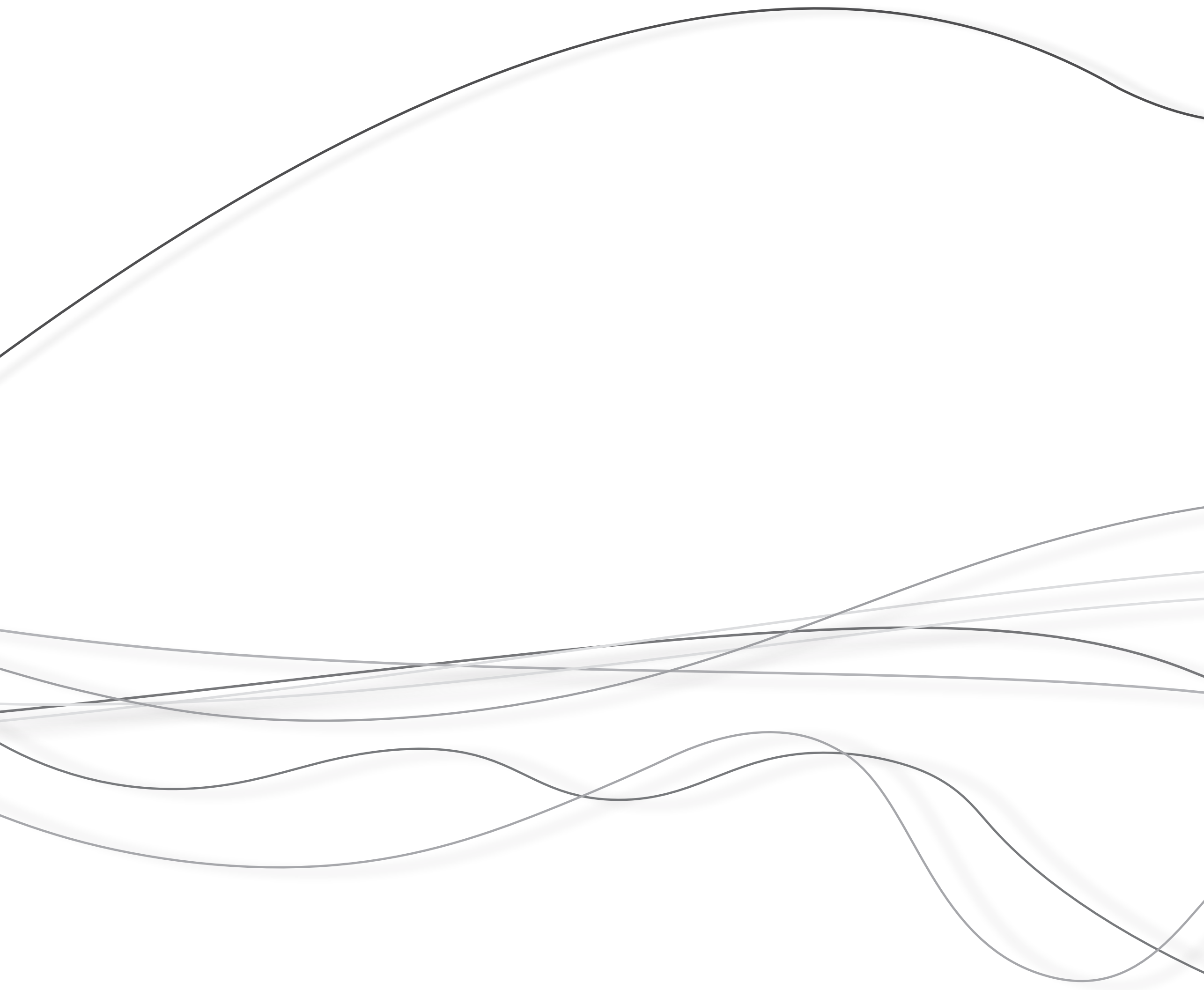

ZUSAMMENFASSUNG

Zusammenfassung

Durch die Nutzung des Internets in den Schulen lesen Schüler vermehrt digitale Texte zum Verständnis (Burnett, 2009; Salmerón, Cañas, Kintsch, & Fajardo, 2005). Diese digitalen Texte mit eingebetteten Hyperlinks und graphischen, beziehungsweise navigierbaren Übersichten, werden auch als Hypertext bezeichnet. Hypertextspezifische Merkmale führen zu einer prototypischen nicht-linearen Strukturierung des Hypertextes.

Das Formen eines kohärenten mentalen Modells mit digitalem Text wird durch die spezifischen Textmerkmale erschwert, verglichen mit ‚traditionellem' linearen Text (Foltz, 1996). Weitere Untersuchungen haben inkonsistente Ergebnisse gezeigt hinsichtlich der relativen Effektivität von verschiedenen digitalen Texten auf den Verstehensprozess (Amadieu, Tricot, & Mariné, 2010). Allerdings sind Untersuchungen mit Kindern selten. Es ist daher unklar wie der Verstehensprozess von Kindern beim Lesen unterschiedlicher digitaler Texte aussieht. Aus diesem Grund zielte diese Dissertation auf die Beantwortung drei relevanter Untersuchungsfragen. Die erste Untersuchungsfrage bezog sich darauf, wie Kinder in unterschiedlichen digitalen Texttypen mit speziellen Hypertexteigenschaften Textverständnis entwickeln (Kapitel 2, 3). Die zweite Untersuchungsfrage beleuchtete, wie Kinder mit verschiedenen digitalen Texttypen und speziellen Hypertexteigenschaften lernen (Kapitel 4). Die dritte Untersuchungsfrage dieser Dissertation bezog sich auf die Frage, wie Kinder beim Lernen mit digitalen Texten unterstützt werden können (Kapitel 5).

Das digitale Textverständnis (Kapitel 2, 3) und das Lernen mit digitalen Texten (Kapitel 4) wurde mit Hilfe von vier unterschiedlichen digitalen Texten untersucht: linearer digitaler Text (LDT), digitaler Text mit navigierbarer Übersicht (DTO), digitaler Text mit eingebetteten Hyperlinks (Hypertext, HT) und Hypertext mit navigierbarer Übersicht (HTO). Das digitale Textverständnis der Kinder wurde *während* des Lesens mit Multiple Choice (MC) Fragen in Kapitel 2 gemessen, wobei das Lernen mit digitalen Texten *nach* dem Lesen mit MC-Fragen in Kapitel 4 und Kapitel 5 gemessen wurde.

Textverständnis und Digitale Texteigenschaften

Um Textverständnis in linearem Text zu erlangen, müssen Kinder über ein ausreichendes Level an „lexical quality" verfügen, welches sich aus dem Worterkennungsprozess und dem Wortschatz zusammensetzt (Perfetti, 2007). Außerdem müssen die Kinder mit den kognitiven Anforderungen während des Lesens umgehen können. Schemaorientierte Ansätze zeigen, dass das Vorwissen und das Arbeitsgedächtnis bedeutsame Faktoren sind, um kohärentes Textverständnis zu entwickeln und um die kognitive Belastung während des Lesens zu reduzieren.

Die Eigenschaften von digitalem Text sowie die Charakteristiken des Lesers beeinflussen den Leseprozess, beziehungsweise die Navigation, und somit die Bildung eines kohärenten Situationsmodells. Die Lesekompetenz und die Aktivierung von Vorwissensstrukturen können den Leseprozess entlasten und sind wichtige Aspekte um ausreichendes Textverständnis mit digitalem Text zu erlangen. Zudem kann dadurch die Orientierungslosigkeit beim Leser in digitalen Texten verhindert werden (Amadieu et al., 2010; DeStefano & LeFevre, 2007; Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009). Die digitalen Texteigenschaften könnten Lesern mit geringem Vorwissen (über das Thema), wie zum Beispiel Kinder, dabei helfen kohärent zu navigieren. Somit könnten Hyperlinks und graphische Übersichten als linguistische Marker in digitalen Texten fungieren. Allerdings haben Untersuchungen ebenfalls ein erhöhtes Risiko einer kognitiven Überbelastung in digitalen Texten gezeigt. Diese mentale Überbelastung bei Lesern mit geringem Vorwissen kann durch die spezifischen Hypertextmerkmale ausgelöst werden, die die Flexibilität im Navigationsverhalten steigern und somit eine erhöhte Komplexität im Leseprozess verursachen (Shapiro & Niederhauser, 2004).

Das Digitale Textverständnis von Kindern

In Kapitel 2 und 3 wurde der Einfluss von digitalen Textmerkmalen auf das Textverstehen von Kindern der 4. Klasse der Grundschule untersucht. Zusätzlich lag der Fokus in Kapitel 2 auf den individuellen Unterschieden zwischen den Kindern. In Kapitel 3 wurden speziell die Unterschiede in den mentalen Repräsentationen der Kinder untersucht. Die Ergebnisse zeigten, dass die Kinder in allen vier digitalen Texten die gleiche Anzahl der MC – Verständnisfragen während des Lesens richtig beantworteten. Die navigierbare Übersicht führte zu keinem positiven Effekt in Bezug auf das Textverständnis. Dies ist auf die hierarchische und geschlosse Hypertextstruktur zurückzuführen, die selbst strukturelle Informationen über die Makrostruktur des Textes an den Leser lieferte (Salmerón et al., 2009). Die Ergebnisse in Kapitel 2 zeigten, dass in Übereinstimmung mit der „lexical quality“ Hypothese der Worterkennungsprozess und der Wortschatz Prädiktoren des digitalen Leseverständnisses von Kindern waren und einen wichtigen Beitrag zum digitalen Leseverständnis lieferten.

In Kapitel 3 wurden die Unterschiede in den Wissensstrukturen der Kinder mit Hilfe der psychometrischen pathfinder Methode von Beziehungsbeurteilungen (siehe auch Kapitel 5) sowie Mindmapping untersucht (siehe Kapitel 4, 5). Die pathfinder Methode ermöglicht die Berechnung der Übereinstimmung zwischen der mentalen Repräsentation eines Kindes und einer sequentiellen Repräsentation, beziehungsweise zwischen der mentalen Repräsentation eines Kindes und der mentalen Repräsentation eines Experten. Die Ergebnisse von Kapitel 3 zeigten, dass Kinder sequentielle Repräsentationen in allen vier Texttypen bildeten. Allerdings zeigten die Ergebnisse ebenfalls, dass die Übereinstimmung beziehungsweise Ähnlichkeit mit dem Expertenmodel das Leseverständnis der Kinder mit Hypertext mit und ohne navigierbarer Übersicht voraussagte. Diese Ergebnisse lassen annehmen, dass das Lesen von Hypertext mit und ohne Übersicht ein elaboriertes und tieferes Textverständnis unter Rückgriff auf Vorwissen fördert.

Das Lernen mit Digitalem Text

In Kapitel 4 wurde der Einfluss von digitalen Texteigenschaften in Bezug auf das Lernen mit digitalen Texten bei Schülern der 5. Klasse des Gymnasiums untersucht. Die Resultate von Kapitel 4 zeigten, dass Fünftklässler gleich gut von allen vier Texten lernten. Die Ergebnisse von Kapitel 5 indizieren wiederum, dass Viertklässler mehr textbasiertes Wissen lernen. Erneut konnte die Eignung von hierarchischem Hypertext für Kinder gezeigt werden (Calisir, Eryazici, & Lehto, 2008). Zusätzlich wurde in Kapitel 4 das Navigationsverhalten der Kinder in den vier digitalen Texten untersucht. Die Resultate zeigten, dass Fünftklässler weniger linear in Hypertext mit und ohne Übersicht navigierten, verglichen mit dem linearen digitalen Text. Außerdem zeigte die gemessene Lesezeit keine Unterschiede zwischen den Texttypen; zudem lernten die Kinder gleich gut anhand von MC-Fragen. Die Fünftklässler formten komplexere Mindmaps nachdem diese Hypertext mit und ohne Übersicht gelesen hatten. Die Ergebnisse von Kapitel 4 zeigten, dass Hypertext die Informationsverarbeitung auf der Repräsentationsebene des Situationsmodells unterstützt, was gleichzeitig in Übereinstimmung mit den Ergebnissen von Kapitel 3 ist, wo gezeigt wurde, dass die mentalen Repräsentationen, die den Experten ähnlich waren, dass Hypertextverständnis vorhersagten.

Hypertext-Strategietraining

Kinder lernen Lesestrategien in der Schule die speziell für lineare Texte entwickelt und untersucht wurden, allerding sind diese Strategien nicht automatisch eins zu eins auf Hypertext übertragbar (Salmerón & García, 2012). Basierend auf dem Konzept des Selbstregulierten Lernens und den vier Lesestrategien (Planen, Bewerten, Elaborieren und Strategiemonitoring) von Zimmermann (1998) wurden in Kapitel 5 Hypertext-Lesestrategien für Viertklässler entwickelt. Diese Strategien wurden den Kindern in einem kurzen Training in Kombination mit Mindmapping vermittelt. Das Training wurde extern reguliert mit einer auf Papier gedruckten Strategiekarte. In Kapitel 5 wurde der Effekt des Strategietrainings auf die Benutzung der Strategien und die Lernergebnisse untersucht. Die Ergebnisse zeigten in der Nachmessung, dass die Trainingsgruppe retrospektiv mehr Strategien nutzte, mehr Textverständnis aufzeigte und mehr fortgeschrittene Mindmaps produzierte, verglichen mit der Kontrollgruppe. Im Allgemeinen zeigten die Resultate von Kapitel 5, dass ein kurzes extern reguliertes Hypertext-Strategietraining in Kombination mit Mindmapping das Hypertextverständnis von Kindern erhöhen kann (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Leopold & Leutner, 2012).

Schlussfolgerung und Praktische Implikationen

Die Ergebnisse der vorliegenden Dissertation lassen den Schluss ziehen, dass Viertklässler mit den kognitiven Anforderungen von hierarchischem Hypertext umgehen können, sobald die Kinder ein ausreichendes Level an „lexical quality" entwickelt haben. Außerdem lernen Kinder in der Grundschule mehr textbasiertes Wissen mit hierarchischem Hypertext. Vergleicht man alle vier digitalen Texte, lernen Fünftklässler gleich gut mit verschiedenen hierarchischen digitalen Texten. Zusätzlich zeigte diese Dissertation, dass Kinder in der Lage sind spezielle digitale Lesestrategien zu lernen und diese mit Hilfe eines kurzen extern regulierten Strategietrainings in Kombination mit Mindmapping anzuwenden.

Lehrer sollten die Kinder dabei unterstützen experten-ähnliche Situationsmodelle zu formen, um das Textverständnis zu erhöhen und elaborierte mentale Modelle zu erzielen. Um dies zu erreichen, sollten Lehrer die Kinder dabei unterstützen, in einer kohärenten Weise durch den digitalen Text zu navigieren (Pressley, 2006). Außerdem sollten Lehrer den Fokus auf die speziellen digitalen Texteigenschaften legen und gleichzeitig auf angepasste Strategien achten, um das digitale Textverständnis bei Kindern zu erhöhen. Im Allgemeinen sollten Kinder dabei unterstützt werden spezifische Lesestrategien für Hypertext anzuwenden.

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DANKWOORD

Dankwoord

"Loopt men op een doel toe, is het uitermate belangrijk op de weg te letten. […] "

"Wenn man auf ein Ziel zugeht, ist es äußerst wichtig auf den Weg zu achten. [...]"

Paulo Coelho

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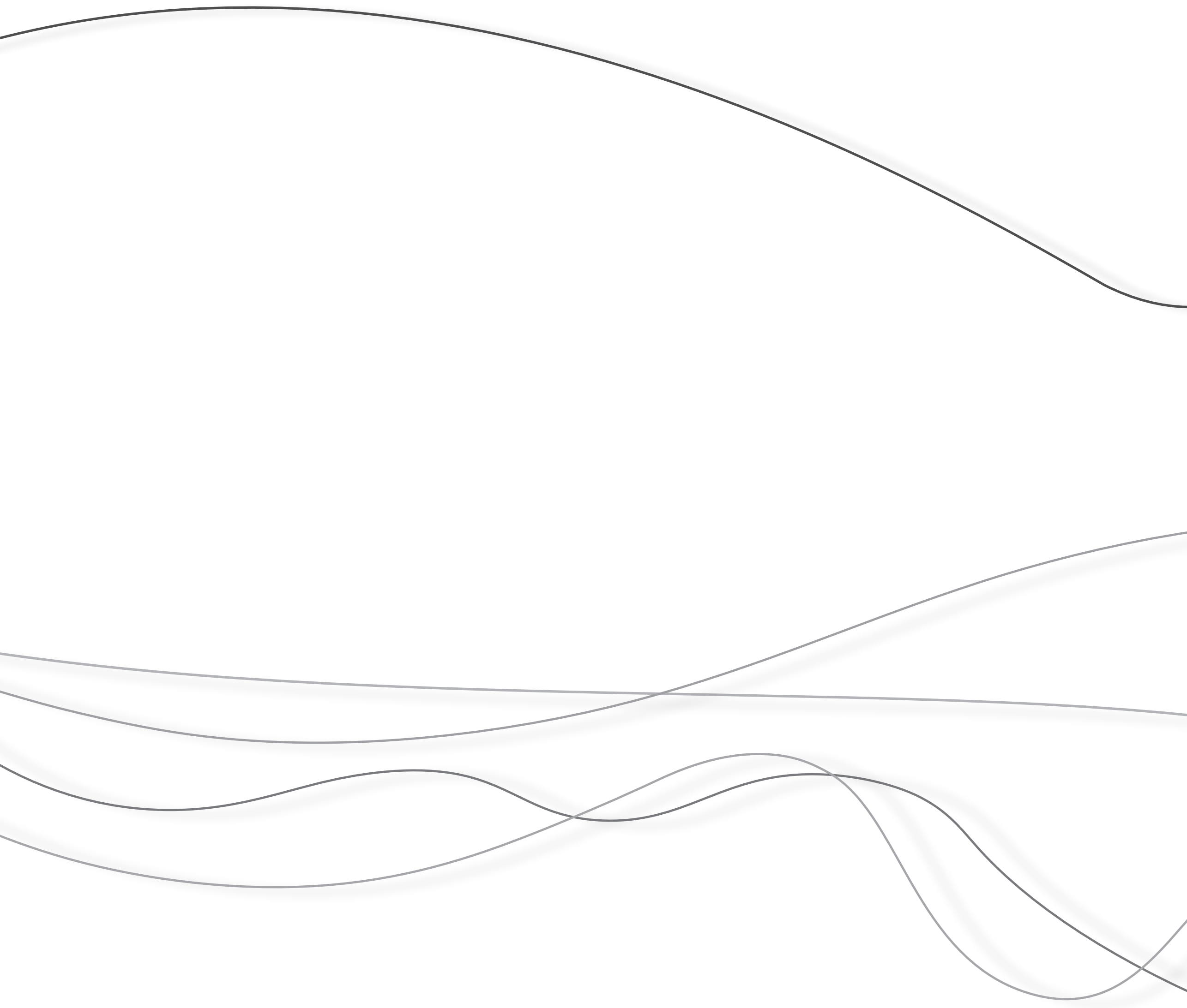

CURRICULUM VITAE

Curriculum Vitae

Sabine Fesel (née Klois) was born on November 29, 1985 in Ruda-Sl, Poland. In 2005 she graduated from the catholic private secondary school Gymnasium St. Christophorus in Werne, Germany. In the same year Sabine started studying psychology at the University of Twente in Enschede, the Netherlands and obtained the Propaedeutics in 2006. Sabine received her Bachelor's degree in 2008, and continued with her Master's program in cognitive psychology at the University of Twente. Sabine conducted her Master's thesis at the Leibniz Research Centre for Working Environment and Human Factors at the Technical University of Dortmund, Germany. She obtained her Master's of Science in Psychology in 2009. Subsequently Sabine started working as a PhD candidate at the Behavioural Science Institute of Faculty of Social Sciences (Radboud University) in Nijmegen, the Netherlands. Next to her research, Sabine worked as a lecturer and supervised students individually during their Bachelor's and Master's Thesis'. In 2013 Sabine received the University Teaching Qualification. In June 2014 Sabine married Philipp Fesel. Since December 2014, she is working as a school psychologist.

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IN DEI NOMINE FELICITER